Vol. XV. APRIL 1931. No. 2.

Entered as second-class matter January 12, 1924, at the post office at Río Piedras, Porto Rico, under the Act of June 6, 1900.
Acceptance for mailing at a special rate of postage provided for in section 1103, October 3, 1917, authorized January 12, 1924

THE JOURNAL
of the
DEPARTMENT OF AGRICULTURE
of PUERTO RICO

MELVILLE T. COOK, Editor.

Nitrogen Transformations in the Decomposition of Sugar Cane Trash, with Special Bearing upon Puerto Rico Soil Problems, *Juan Amédée Bonnet.*

A Bibliography of the Banana Root Weevil, *Mortimer D. Leonard.*

The Effect of Mosaic Virus on Cell Structure and Chloroplats, *Melville T. Cook.*

The Leaf Spot of Tobacco; an After Symptom of Mosaic, *Melville T. Cook.*

Some Undescribed Symptoms of Mosaic in Porto Rican Tobacco, *Melville T. Cook.*

New Virus Diseases of Plants in Porto Rico, *Melville T. Cook.*

PUBLISHED BY
THE INSULAR EXPERIMENT STATION
RÍO PIEDRAS, P. R.
(ISSUED JUNE 1931)

SAN JUAN, P. R.
BUREAU OF SUPPLIES, PRINTING, AND TRANSPORTATION
1931

Exch.
Insular Exp. Sta.
8-25-31

DEPARTMENT OF AGRICULTURE AND LABOR

SUPERIOR OFFICERS

EDMUNDO D. COLÓN, M. S.——Commissioner
JAIME BAGUÉ, V. M. D. ——Sub-Commissioner

INSULAR EXPERIMENT STATION STAFF

R. FERNÁNDEZ GARCÍA, M. S.——Director
MELVILLE T. COOK, Ph. D. ——Vice-Director

DIVISION OF CHEMISTRY

R. FERNÁNDEZ GARCÍA, M. S.——Chief Chemist
ISMAEL COLÓN, B. S. ——Associate Chemist
FERNANDO A. VILLAMIL, B. S.——Assistant Chemist
BERNARDO CAPÓ, B. S.——Assistant Chemist
JUAN A. BONNET, M. S.——Research Chemist
JOSÉ M. PARDO, M. S.——Biochemist

DIVISION OF AGRONOMY

P. RICHARDSON KUNTZ, B. S.——Chief of Division
FERNANDO CHARDON, B. S.——Assistant Agronomist
THOMAS BREGGER, Ph. D.——Plant Breeder
POLICARPO GONZÁLEZ RÍOS, B. S.—Pomologist
PEDRO OSUNA, B. S. ——Horticulturist
E. H. TWIGHT, M. S.——Citrologist

DIVISION OF ENTOMOLOGY

MORTIMER D. LEONARD, Ph. D.——Chief of Division
FRANCISCO SEÍN, JR., B. S.——Assistant Entomologist

DIVISION OF PLANT PATHOLOGY

MELVILLE T. COOK, Ph. D.——Chief of Division
ARTURO ROQUE, M. S.——Assistant Pathologist
ROBERTO MUÑOZ MCCORMIC, B. S.—Assistant Pathologist

DIVISION OF ANIMAL HUSBANDRY

MONTGOMERY ELLISON, B. S.——Chief of Division
JUAN VARAS CATALÁ, V. S.——Veterinarian
MIGUEL GARCÍA DÍAZ, B. S.——Assistant Animal Husbandman

ISABELA SUB-STATION

LUIS A. SERRANO, B. S.——Agronomist in Charge
GEORGE N. WOLCOTT, Ph. D.——Entomologist
CARLOS J. CLAVEL, B. S.——Assistant Agronomist
MARIANO MATOS, B. S. ——Assistant Agronomist
CARLOS ESTEVA, JR., M. S.——Assistant Agronomist
SALVADOR VIVES——Extension Specialist

OFFICE

ROBERTO L. RIVERA——Chief Clerk and Acct.
JOSÉ I. OTERO——Librarian

The Journal of the Department of Agriculture
OF PORTO RICO

Published Quarterly: January, April, July and October of each year.

MELVILLE T. COOK, EDITOR

VOL. XV APRIL 1931 NO. 2.

NITROGEN TRANSFORMATIONS IN THE DECOMPOSITION OF SUGAR-CANE TRASH, WITH SPECIAL BEARING UPON PUERTO RICO SOIL PROBLEMS.*-**

JUAN AMÉDÉE BONNET,

Researeh Chemist, Puerto Rico Insular Experiment Station.

INTRODUCTION

Sugar cane is the most important crop of Puerto Rico. As the area for sugar cane cultivation is limited, it has been necessary to increase the yields of tonnage and sucrose content in the sugar cane with the lowest possible cost. The 1910 production of the Island was 349,840 short tons of sugar. In that year, the Puerto Rico Sugar Growers' Association established an Experiment Station at Río Piedras, Puerto Rico, which in 1914 passed under government control. In its twenty years of active work attention has been given to various phases of tropical agriculture. Experimentation based on modern principles of soil science management has been applied to the cultivation of the sugar cane.

From 1911 to 1920, inclusive, the average production of the island was 414,426 short tons of sugar. During the last ten years the total production in short tons of sugar has been as follows:

1921	489,817	1926	606,464
1922	408,325	1927	630,202
1923	379,171	1928	751,332
1924	447,587	1929	586,760 *
1925	660,532	1930	872,326

The area under sugar-cane cultivation from 1915 to 1924 was between 203,105 to 256,431 acres. During the last years the area under cultivation has been, more or less, 242,000 acres. The 1930

* Part of a thesis submitted on May 10, 1930 to the faculty of Rutgers University, New Brunswick, New Jersey, in partial fulfillment of the requirement for the degree of "Master in Science".

** The writer wishes to express his appreciation to Dr. Selman A. Waksman, who supervised the work, for the many valuable suggestions and criticisms offered throughout the experiment. The thanks of the writer also are due to Dr. Robert L. Starkey, for advice and help.

* Decrease due to hurricane of September 13, 1928.

crop showed an increase of 93.51 per cent over the 1924 crop. The application of soil science principles have been successful in saving many a sugar-cane grower from dreadful bankruptcy. New sugar-cane varieties, scientific applications of fertilizers, modern methods of field cultivation, and the proper use of machinery, irrigation, and drainage have been among the factors which contributed to the increase in the sugar-cane production of Puerto Rico to its present status.

THE ORGANIC MATTER PROBLEM

In the 1927–1928 report of the Insular Experiment Station of Puerto Rico, the present director, R. Fernández García says: (8)

"It is our belief, as has been pointed out in previous reports, that the apparent degeneration of cane varieties as shown by their susceptibility to diseases and pests and their ever-decreasing yields is not a degeneration of the varieties but is due to unfavorable changes in the soil conditions brought about by our present agricultural practices.

"Our inability to return to the soil, under present practices, the organic matter that is lost by tillage must necessarily not only lower the organic matter content of the soil but its quality and rate of decomposition. This continued loss of organic matter results in very unfavorable conditions for the plant and new varieties have to be imported or bred that will tolerate such conditions."

The organic matter of a soil is supplied by a great mass of substances of plant, animal, and microbiological origin. It is dynamic in nature and has a complex, variable composition. Its decomposition in the soil is mainly biological and greatly improves the chemical and physical properties of the soil.

Organic matter decomposition supplies the soil solution with carbon dioxide. The carbonated water renders soil nutrients soluble which can thus be taken by the higher plants. Organic matter improves the physical properties of the soil, such as, moisture-holding capacity, buffer effect, mineral absorption, temperature, etc., and introduces certain rare elements usually not brought in the organic fertilizers that may have some stimulating action on plant growth.

The additions of inorganic fertilizers to the soil supplies nutrients for the needs of the sugar-cane plant, but does not replenish the losses of organic matter. It requires a great outlay of money to supply organic matter to the soils with applications of organic commercial fertilizers. It has been economically advisable in many occasions to use green manure crops as a source of organic matter. It has been found also advisable to incorporate to the soil the straw which is left as waste in the wheat and sugar-cane fields.

The nitrogen added to the soil in the form of organic fertilizers

or organic residues is not present in an available form. It is this property which makes them frequently very valuable, especially, in wet districts. The nitrogen is not readily washed out and is gradually made available to the plant in the course of time. The addition of organic matter furnishes certain organic compounds which are used for structural and energy purposes by the non-symbiotic nitrogen fixing organisms. Leguminous plants serve as a host for the symbiotic nitrogen fixing organisms.

The physical condition of the heavy clay soils which are so common in the sugar-cane fields are greatly improved by the addition of undecomposed organic matter. The carbon dioxide produced in the decomposition processes makes the heavy soils more porous. It is more advisable to apply organic matter after it has been partly decomposed, to sandy soils. Under these conditions the coarser particles will be cemented by the colloidal "humus".

There is sufficient evidence to justify the belief that another important use of the organic matter is to supply during its decomposition certain compounds partially synthesized for the use of the plant. Knudson (**10**) showed in Cornell that corn absorbs and assimilates glucose, fructose, saccharose and maltose. It is not illogical to expect similar results from the use of amino acids and other products of protein decomposition.

The conservation of soil organic matter must be studied in relation to the plant, the soil and its microbiological population.

Some workers have associated the phenomenon of organic matter decomposition in soils with that of "denitrification". When such a nitrate reduction process goes to completion, nitrogen is lost in a gaseous form, either, as atmospheric nitrogen or as oxides of nitrogen. This concept made many farmers regard the addition of organic matter to their soils as an undesirable process.

Denitrifying organisms are active largely under anaerobic conditions. It is favored by excess of water and organic matter. When a solution of certain nitrate salts is inoculated with denitrifying organisms losses of nitrogen are observed. Such a phenomenon occurs in the soil in an entirely different way. When a soil is not too moist there could be partial reduction of nitrate salts to nitrite and ammonium salts without the reduction going further to gaseous nitrogen. As soon as the soil conditions favor the activity of the nitrifying organisms the ammonium salts will be reoxidized to nitrite and nitrate salts. The conclusion may be reached that the phenomenon of denitrification is of no economic significance in well aerated, not too moist soils, in the presence of moderate amounts of organic matter.

Under normal field conditions, usually, the nitrogen is transformed to less available organic forms by the microorganisms concerned with the decomposition processes of organic matter which need available nitrogen for building their cell protoplasm. In course of time the nitrogen is made again available. In the process of cell building the microorganisms compete with the plant for the available nitrogen. The carbon-nitrogen ratio of the organic material under decomposition is of special importance in this connection. It has been shown that there exists a more or less constant ratio between the nitrogen and carbon content of the soil, whatever the ratio was between these elements in the organic matter originally added to the soil. This ratio varies from 1:8 to 1:12, i. e., for every part of nitrogen there exists in the soil eight to twelve parts of carbon; the average ratio is about 1:10.

. There is no appreciable effect upon the soil nitrate if the nitrogen of the organic matter added is about 1.8 per cent. (**18.**) A higher nitrogen content allows a rapid accumulation of ammonia and nitrate in the soil. Such is the case when dried blood, cotton seed meal, urea of other organic material with a high nitrogen content, and therefore, with a narrow nitrogen-carbon ratio is added to a normal soil. When the nitrogen-carbon ratio of the soil is wider than normal, plant growth suffers and nitrogen starvation will be observed as long as the excess of carbon lasts, since the microorganisms using the carbon as a source of energy will assimilate every trace of nitrogen that would otherwise be utilized by the higher plants.

As straw and sugar-cane trash have nitrogen-carbon ratios as wide as 1:80 it would not be advisable to incorporate such materials to a nitrogen starving soil unless nitrogen is supplied. If the sugar-cane trash is allowed to decompose a few weeks previous to planting, nitrogen starvation of the plant is not so noticeable.

Soil microorganisms may obtain their nitrogen from protein and their degradation products or simple inorganic nitrogenous compounds, including the ammonium salts and nitrates. Some organisms, especially the heterotrophic bacteria, prefer and many even require complex proteins, albumoses or peptones as a source of nitrogen (and energy), while other microorganisms, especially the fungi and autotrophic bacteria, will thrive just as well and sometimes even better upon simple compounds of nitrogen. The minerals, chiefly phosphates and potassium salts, but also iron, magnesium, sulphur, calcium and traces of other elements, are utilized by all microorganisms either in the form of simple inorganic compounds or are obtained from complex organic substances in the process of their decomposition. The mine-

rals may often be obtained from insoluble inorganic materials, especially if the organism produces acids which tend to make them soluble.

Temperature and moisture conditions in the tropics accelerate organic matter decomposition because they favor the activities of a group of soil microorganisms (heterotrophic) capable of breaking organic substances to use the carbon and free energy for their metabolic needs. The action of such microorganisms may be direct or through the agencies of enzymes. The protein nature of the microorganism protoplasm furnishes sources of proteins further decomposed by fungi and bacteria through polypeptides, amino acids and ammonium salts. The oxidation of the ammonium through the nitrite and nitrate stages furnishes energy for the activities of the nitrifying organisms. The sugars liberated in organic matter decomposition furnish energy for the non-symbiotic nitrogen fixers.

As organic matter is essential for microbiological life it is necessary to supply it to the soil, at intervals. If this is not done, a great part of the soil organic matter will be wasted as carbon dioxide into the atmosphere.

SUGAR CANE TRASH

The great bulk of the organic matter in the sugar cane fields is furnished by the leaves, leaf sheaths and tops of the sugar cane plant, which, in the form of trash are left in the field. Most of the green tops are used as fodder for farm animals. Dead roots contribute a small part. Maxwell (**13**) reports in 1898 an average of 33 per cent of total trash per ton of cane per acre for the Hawaiian crop. The weight of roots was considered to be very small, namely, about 4 per cent. (**14**.)

The bulkiness of the trash interferes with the crop cultivation. The most rapid method of getting rid of it is by burning. Sometimes this is done as a means to cut down field expenses. The trash is burnt either before or after cutting the crop. Claim is made that fire does not injure the following crop in its germination power and that injurious insects are destroyed.

Burning off destroys the borer parasite, but not always the borer. (**13**.) The borer is usually sheltered in the rotten cane left on the land which protects the insect from the fire effects. In 1916, Wolcott (**30**) reported that burning off increases borer infection 100 per cent.

Studies have been made on the effect of fire on tonnage and sucrose yield when the harvest is delayed for a few days. López Domínguez (**11**) in Puerto Rico experimenting with Cristalina and P.R.–209 canes found that when subjected to fire while standing in

the fields, or if stored, the canes lost about 2 per cent of their original weight per day. The loss in weight caused by delayed milling was greater in the burned canes than in the unburned ones. The burned cane suffered inversion both when cut and when left standing in the field, but the standing cane suffered greater losses in sucrose than the cut cane. At the Ewa Plantation, (**20**) Hawaii, H-109 harvested five, ten, fifteen days after burning, lost respectively; 14.72 per cent, 29.7 per cent and 20.29 per cent, of the original weight. Burned cane cut at once and burned cane allowed to stand until milled differed little in sugar losses. Alincastre (**3**) says:

"Cane burning before cutting permits loss of sap and decomposition by microorganisms. Losses occur after 24 hours which offset the decreased harvesting cost."

O'Brien (**16**) also condemns this practice.

In Puerto Rico, a few plantations burn the trash when harvesting the ratoons. Most manage to handle the trash during the cultivation of the ratoons; but when the land is to be prepared for a new crop the field is cleaned by means of fire. In the irrigated fields of a certain large plantation the trash is burned. In their non-irrigated fields the usual custom for fall-planting is to leave the trash on the ground while preparing the field, raking it to one side and spreading it over after the planting is made. With spring planting, they always burn the trash. When there is too much straw while the ratoons are under cultivation it is the usual custom to bury part of the straw in the rows.

In the low lying lands of some plantations located at the western section of Puerto Rico, large amounts of trash are moved about by the floods and deposited in heaps. It is expensive to handle the piles of mud and trash. So; in these fields, trash is usually burned.

The following comments on sugar cane trash are taken from the report (**12**) presented by the Puerto Rico delegates on the 1927 International Meeting of Cane Technologists held at Havana:

Taggard, Louisiana:

"As trash buried at a great depth does not decompose, beneficial effects such as: addition of organic matter, improvement of soil physical conditions and addition of inorganic nutrients to the soil, are not obtained. For this reason in Louisiana the trash is slightly covered with soil."

Moir, Hawaii:

"The practice in Hawaii is to burn the trash. So far no evil effects have been observed in the soil."

Agee, Hawaii:

"The roots that remain in the soil are sufficient to maintain the organic matter equilibrium in the soil."

Menéndez Ramos, Cuba:

"The most beneficial effect from the trash is the preservation of soil moisture and checking of weeds growth. The mulch effect is of more value than the fertilizer nutrients added to the soil."

It was also reported:

"In Cuba, the yields per acre were higher in certain fields where the trash was burned. This was attributed to the fact that no cultivation was given to the fields where the trash was left; while those where the trash was burned were carefully cultivated. Borer infection was higher where the trash was burned."

Storey, South Africa:

"Experiments were made with Adco and trash, to convert the latter into humus. The trash must be left moist. Trash was converted into humus in three months during the summer."

López Domínguez and del Valle (**12**) summarize those statements as follows:

"The results in Cuba indicate that it would have been better to cultivate the soil and line the trash. As to the non-evil effects observed in Hawaii from burning the trash, it must be considered that the Hawaiian soils are very porous, and that cane in Hawaii has been an important commercial crop for the last twenty-five years only. In Louisiana, where cane is grown since the 17th. century in alluvial soils heavier than those of Hawaii and where field methods have been carefully studied, it is not burned. In Puerto Rico with its heavy soils under cultivation for several generations and where the borer exists, the trash should not be burned. Means must be studied to handle the trash in the most economical way which at the same time is the most beneficial to the fields. The questions to be answered are: Is the trash to be buried or left over the surface? Must the trash be lined or spread over the whole surface?"

The increase in sugar cane yield in a field where trash is burned as has been observed in Cuba and Hawaii may be due to a partial sterilization effect whereby the nutrients are rendered more available for the use of the crop. It is a temporary effect which may last till the soil exhausts its natural supplies. Part of the available minerals accumulating on the porous soils of Hawaii after the trash is burned may be lost through leaching.

Agee's comment was reported in 1924 by Mc. George (**15**) as follows:

"To determine if the current practice of burning the trash in the Hawaiian islands, was depleting the organic carbon of plantation soils, 42 samples of Ewa soils representing cultivated and uncultivated portions of nine fields, were analyzed for total carbon content (little or no carbonate carbon being present in coral soils.) In these fields the organic content in four was lower, and in five higher, in the cultivated than in the uncultivated portions. The variations were, for cultivated fields, from 0.85 to 1.93 per cent with an average of 1.30 per cent and, for the uncultivated, from 0.74 to 2.60 per cent with an average or 1.37 per cent. In these fields the trash is always burnt, and there appears to be no indication that there is any depletion of the organic carbon content, the roots and stubble presumably being sufficient for keeping it up."

Such results, however, could not be considered as significant unless proved to be so, by statistical methods. De Turk (**7**) says:

"The variability of field soils makes the problem of determining increases in organic matter brought about by a treatment a difficult one, requiring great care in selecting similar pairs of plots for comparison. It was assumed that composites made up of twelve borings would give samples sufficiently representative of the soil of the plots. The probable error for 12 borings was 0.76 per cent of the mean or 50 to 450 pounds of organic carbon per acre."

The results obtained with the Adco treatment may also be obtained if the proper compost is prepared by adding a mixture of fertilizer salts to the trash. Adco, is a mixture of fertilizer salts that serve as a supply of nutrients for microorganisms. The compost is prepared by adding 150 pounds of Adco to a ton of straw. Sufficient water is added to make about three tons of manure. The question to be settled is whether or not the Adco treatment is economical. In the preparation of an adequate manure Albrecht (**2**) recommends:

"A mixture consisting of 45 pounds of ammonium sulphate, 15 pounds of acid phosphate, and 40 pounds of finely ground limestone at the rate of 150 pounds per ton of straw, will, with moisture, convert straw into a brown product having all properties of manures."

According to Noel Deerr: (**6**)

"It is the custom in Hawaii, Demerara, and Java to burn the trash. In Mauritius, much of the trash is used as bedding for the plantation stock and thus finds its way back to the soil as pen manure. A similar routine is followed in the British West Indies. In Cuba it is the almost invariable custom to let trash rot on the fields, where it remains as a blanket. To this custom the long continued fertility of the Cuban cane lands is to be attributed.

"During the period 1901–13 extensive experiments were made on a Hawaiian plantation, in all 109,990 tons of trash being buried."

The effect of this procedure is thus described: (**6**)

"Where two ratoons were formerly the maximum, four are now becoming the rule. The yields, instead of decreasing with each subsequent ratoon, have increased. The 1908 crop was the first one to have trash left over its entire ratoon area. That and the succeeding crops show an average yield of 4.102 tons of sugar per acre; the seven preceding crops gave 3.329 tons of sugar per acre. The 1914 crop to date has yielded 5.2 tons per acre and is expected to go still higher. While all the credit cannot be given to trash, there is no doubt whatsoever that leaving the trash has been the principal factor."

The actual operations in Hawaii followed on a rainfall plantation are described by Larsen: (**6**)

"After the cane is cut the trash is hoed away from the stools into the furrow. This work requires about two men per acre per day and is called 'pali-pali-ing'. This is followed by off-barring, which consists of ploughing off or away from the stools. The soil by this operation is thrown against and partly over the trash and assists materially in hastening its decay. A ten, twelve or fourteen-inch plough is used for off-barring. A revolving knife or sharp coulter is attached to the ploughbeam to make a clean cut ahead of the plough. One man with two mules can off-bar 2 to 2½ acres per day. After off-barring, hoeing is done in the cane lines. In the furrow, that is, between the lines of cane, the weeds in most cases are kept down effectively by the trash. Cultivation between the rows begins from one to two months after pali-pali-ing. After two or three more hoeings in the cane rows as occasion demands and as many more cultivations the trash will have become so thoroughly broken up and disintegrated that the furrow can be small-ploughed without trouble. A small eight-inch plough is run usually four times through the furrow to loosen up the soil and to mix in the trash. After small-ploughing, the cane is hilled. This is done with hoes, ploughs, double mould-boards, or discs. With this operation the rotted and partly rotted trash is thrown toward the cane and is more thoroughly buried and mixed with the soil."

In certain soils in Demerara the presence of decaying trash has, according to Harrison (**6**) a specific function in neutralizing the effect of the large quantity of alkaline soil water there present. On this point he writes:

"In experiments in which (*a*) soil water was allowed to evaporate into the air and (*b*) caused to evaporate in an atmosphere consisting almost entirely of free carbon dioxide it was observed that when the evaporation takes place in air, nearly free from carbon-dioxide gas, practically the whole of the lime salts are deposited as calcium carbonate, while the water is being concentrated to one-third of its original bulk, and the remaining water becomes a saline one, containing large quantities of magnesium salts as chlorides, sulphates and carbonates in solution. The calcium salts, which are known to exercise a profound influence in reducing the highly toxic action of the magnesium chloride and carbonate on plants, are almost wholly removed from solution and the soil water becomes in a condition which is poisonous to vegetation; this is probably what takes place during prolonged periods of dry weather or more or less worn-out cane soils, in which by injudicious cultivation and especially by long-continued destruction of

the trash by burning, the normal proportion of organic matter has been largely reduced. When, on the other hand, the evaporation takes place in an atmosphere heavily charged with carbon dioxide, as in the air present in soils containing the proportion of organic matter normal to good soils, the calcium salts remain for a long time in solution until the liquid commences to become a saturated brine, and this for a prolonged period continues to modify the toxic action of the magnesium salts. It is possible on such land that the soil water during drought may become concentrated in the upper layers of the soils, without any material injury to the plant, until by concentration of the soil water the toxic action of the magnesium salts exerts itself."

Cross, (**5**) Director of the Tucuman Experiment Station, recommends the following procedure:

"It is practically feasible to leave the trash without burning, in every second middle, cultivating the other one, and every year to alternate the middle so treated. The soil benefits from the nitrogen and organic substances and the sugar yields are increased. The procedure is particularly recommended for plantations invaded by weeds."

In 1914, in Hawaii, special rakes were prepared to handle the trash. (**1**.) Mr. F. E. Hance, acting chemist of the Hawaiian Sugar Planters Experiment Station, reports in a letter to the writer dated March 12, 1930:

"In Hawaii, no special implements are in use for handling the trash. The custom is to ripen the cane and burn the trash. In the winter time and at all times in some plantations trash remaining on the ground is ploughed under, if the field is to be replanted."

Klinge (**9**) reports:

"Trash is burned in Hawaii as well as in Peru with the difference that in Hawaii the burning is done in situ and in Peru is done in the rows where the trash is piled after raking it from the field. After cutting the cane in some irrigated fields of Hawaii, the trash is raked towards every other furrow. The intermediate furrow is used for irrigation purposes. The practice of burning the trash followed by those plantations that only depend on rain water for cane growth is very variable. Some plantations burn the trash; while others leave it to rot in the soil. Complete burning cannot always be carried on when the continuous rains keep the trash moist. Under these conditions sufficient unburnt trash remains on the soil."

In Java (**19**) trash is either transported to the factory to be used as fuel or is burned in the field as a means to clean the soil for the rice crop. It is the custom to get two successive rice crops after the sugar cane crop. Part of the rice straw is incorporated to the soil. The cane is never burned before cutting; special precautions are in fact taken against accidental fires by removing trash at least thirty feet away from nearby roads.

Owen (**17**) reported in 1926 on work done at the Louisiana Experiment Station:

"Adding undecomposed trash to the soil, resulted in a rapid loss of nitrates, but this depressing action upon nitrates disappeared rapidly with the trash decomposition. The addition of fresh trash caused a marked increase in the soil fungi and increased the ratio of fungi to total number of microorganisms. The depressing effect of trash upon the soil nitrates has been traced to the starch and pentose content of the material."

Bonazzi (**4**), on studies at the Chaparra Experiment Station, Cuba, referred particularly to the influence of the incorporation of sugar cane trash on the moisture content of soil:

"Greatest retention of moisture is to be obtained by allowing the cane leaves to accumulate on the surface of the land. Incorporating the leaves in the soil through ploughing or cultivation does not justify the additional expense. Denitrification is strongly active in presence of cane leaves incorporated with soil. When nitrates were applied in the form of sodium nitrate the losses were very large, whereas in the soils receiving easily assimilable carbohydrates, but no nitrate, the formation of a small quantity of nitrates from the natural soil stores of nitrifiable substance was followed by its early disappearance. The same path was followed by the soils receiving their nitrogen in the organic form.

"The formation of nitrates from tankage in soils containing cane leaves was not cumulative but reached a maximum aften ten days, followed by a rapid disappearance during the second period of incubation. This experiment indicates that great care should be taken not to incorporate cane leaves and trash in the soil at a time of active nitrate formation in the soil. Such a practice would prove deleterious to the growing cane."

A series of plot experiments at the Insular Experiment Station, Puerto Rico, was arranged as follows: (**8**)

(1) One and a-half tons air-dried chopped cane trash + 800 pounds $(NH_4)_2SO_4$ per acre.
(2) Treatment (1) + 2 tons $CaCO_3$ per acre.
(3) Check.
(4) One and a-half tons of cane trash + 2 tons $CaCO_3$ per acre.
(5) One and a-half tons of cane trash per acre.

The land was kept free from vegetation. The effect of cane trash on soil nitrates was followed for a period of 23 weeks. It was found that the addition of trash alone lowered the level of nitrate concentration in the soil. The addition of sulphate of ammonia to the trash raised the level of nitrate concentration to a maximum of eighty pounds per acre over the check in 21 weeks. The pH of the soil was 7.44. In the first treatment, nitrification was slower at the start; but from the eighth week on surpassed that of the second treatment.

In another series of plot experiments at the same Station, the equivalent of 1½ tons of trash per acre was added to a clay soil and sown to soybeans. (**8**.) The gain in yield of this plot was 201 per cent ± 33 per cent over the check. Plots with loam soil given a gain in yield over checks of only 160 per cent ± 12 per cent. The same plots planted to BH–10(12) after incorporating the soybeans did not show such striking difference in yield.

Chemical studies of organic matter decomposition have been greatly based on determination of carbon, nitrogen, ash and loss by ignition. The loss in dry weight was also considered. Such analyses do not give information of what actually happens in the course of organic matter decomposition. To understand the decomposition of sugar cane trash in the soil it is important to gain information concerning the nature of the different groups that form the organic complex. The classification of the various chemical plant constituents into a series of definite groups as proposed by Waksman (**27**) is a great tool for the study of organic matter decomposition in the sugar cane fields. The various chemical plant constituents are divided into the following groups:

"1. *Water-Soluble Constituents.*—These include the most readily available nutrients, both for the growth of the plant and for the growth of microorganisms, when the plant is undergoing decomposition. These constituents comprise a number of organic and inorganic substances, such as the sugars, various glucosides, amino acids, and certain simple proteins among the former, while the latter includes nitrates, phosphates, sulphates, chlorides, potassium salts, etc. This group of plant constituents is highest when the plant is young, making up as much as 40 per cent of the dry matter of the total plant material. This percentage decreases with age, so that mature plants may contain only about 5 per cent of water-soluble constituents, these proportions depending of course also on the nature of the plant and available nutrients.

"2. *Ether and Alcohol-Soluble Constituents.*—They comprise the fats and oils, waxes and resins, tannins, terpenes, alkaloids, and various pigments. They make up only a small portion of the plant, usually 2 to 6 per cent.

"3. *Celluloses.*—These form in most plants the largest single group of constituents, ranging from 15 to 40 per cent of the dry weight of the plant material. They are polysaccharides which serves the function of protective substances in the plant and they are not hydrolyzed by dilute acids and alkalies. They are rapidly decomposed, however, under certain conditions by various specific bacteria and fungi.

"4. *Hemicelluloses.*—These and allied carbohydrates, not included in the sugars and in the celluloses, play a function of both reserve and protective substances in plants. They are also polysaccharides of the pentose or hexose group and are hydrolyzed by dilute acids. They make up 10 to 30 per cent of the plant constituents. Some of them are decomposed even more rapidly than the celluloses, while others are more resistant.

"5. *Lignins.*—Lignins are the so-called incrusting substances in plants. Both lignins and celluloses, which form in the plant complexes of a chemical or physical nature known as ligno-cellulose, are low in young plants and increase in proportion with the age of the plant, both in total quantity and in relation to the other plant constituents. The lignins, which make up 5 to 30 per cent of the dry plant material, are most resistant to decomposition in the soil.

"6. *Proteins.*—These substances play an important function in the nutrition of the plant and in the decomposition of the plant residues in the soil, since they are largely the carriers of the important element nitrogen, as well as of some of the phosphorus and sulphur. In view of the fact that the nitrogen is liberated in the form of ammonia, as a result of the decomposition of the proteins, it was usually assumed that it is sufficient to measure the rapidity of ammonia accumulation from protein decomposition in the soil. However, we come to recognize now that, in the presence of celluloses and hemicelluloses, which are readily used as sources of energy by microorganisms, a part, if not all, of the nitrogen which is liberated in the decomposition of the proteins may be reassimilated by the soil microorganisms and changed into microbial cell substances. The nitrogen (or protein) content of plants is high at an early stage of growth and decreases with an increase in the maturity of the plants, frequently from 18 per cent protein in the young plants to about 1.2 to 1.5 per cent in the mature straw.

"7. *Minerals.*—These include phosphates, sulphates, chlorides, nitrates, and silicates of potassium, calcium, magnesium, iron, aluminum, etc., some of which are water-soluble and others insoluble. They form the ash content of the plant, although some are also present in the proteins (S, P). They make up from 1 to 12 per cent of the total plant constituents. They are high in young plants and diminish, in proportion to the other plant constituents, with maturity of the plants. The nature of the minerals in the young and old plants differs not only quantitatively but also qualitatively, the soluble minerals predominating in the younger plants and the insoluble in the other plants.

"In these seven groups of complexes we can account for practically 90 to 96 per cent of the plant constituents."

EXPERIMENTAL

COMPOSITION OF SUGAR-CANE TRASH

Analyses were made of two samples of trash which were used in subsequent experiments. The first sample was obtained from a field of POJ–2714, adjoining the United States Field Station at Canal Point, Florida.* It was gathered from the soil surface around cane in the dry form and was further sundried before shipment. The second sample of sugar cane trash was taken at the Everglades Experiment Station, Florida,* as dead leaves from the lower part of the stems of SC–12(4). Before shipping, it was thoroughly dried in the greenhouse. The samples were ground in a No. 1 Wiley mill and sifted through a 1mm. sieve.

* Thanks are extended to Dr. B. A. Bourne, Canal Point, and Dr. R. V. Allison, Everglade Experiment Station for furnishing the samples of sugar-cane trash.

The approximate complete analysis of the sugar-cane trash was carried in duplicate as follows:

Moisture, total nitrogen and ash.

Six-gram portions were analyzed as follows: (**29**)

(*a*) Extracted with ether in Soxhlets for 16 hours.

(*b*) Residue was extracted for 24 hours with 100 cc. of cold water.

After filtering, the residue was washed several times with cold water. The filtrate was made to volume and divided into three portions, one used for reducing sugar, one for total nitrogen after evaporating excess of water and one for total soluble organic matter by evaporating and drying to constant weight. Ash determinations were carried on after igniting the organic matter.

(*c*) Residue from (*b*) was treated for 3 hours with 100 cc. of hot water over boiling water bath. The solution was analyzed as in (*b*).

(*d*) Residue from (*c*) was treated twice with 100 cc. of 95 per cent alcohol.

The flask was placed for 2 hours on a boiling-water bath. The filtrate and washings were evaporated to constant weight. The difference between the weight of the paper with the residue and that of the original paper gives the weight of the plant material from which the ether and water-soluble, as well as the alcohol-soluble portions have been removed.

The sum of the weight of fractions (*a*), (*b*), (*c*) and the weight of the plant substance left after the alcohol extraction was taken as the quantity of the original dry plant material taken for analysis. All calculations were based on such weight.

(*e*) The residue from (*d*) was treated with 100 cc. of a 2 per cent solution of hydrochloric acid and autoclaved for five hours under flowing steam. The solution was filtered off through dried and weighed filter papers. The residue was washed with dilute acid and then with water until free from acid. The filtrate and washings were analyzed for reducing sugars by the Bertrand method, and for total nitrogen. The hemicellulose content was obtained multiplying the reducing sugars by 0.9.

(*f*) The washed residue from the hydrochloric acid extraction was dried to constant weight. Two 1-gram portions of the dry material were treated with 10 cc. of 80 per cent sulphuric acid, for 2 hours, in the cold. The acid was brought in contact with all particles of the material by stirring. After 2 hours, 150 cc. of distilled water were added to each treatment and the contents were autoclaved for 1 hour at

15 pounds pressure. The contents were filtered through small dried and weighed filter papers. The residue was well washed with water to free from traces of sulphuric acid. The combined solution and filtrate was analyzed for reducing sugars. The cellulose content was obtained multiplying the reducing sugars by 0.9. Of the four residues for each original material, two were used for ash and two for nitrogen determinations. Weight of residue —(ash + nitrogen × 6.25)= lignin content. The cellulose and lignin found in the one gram portion of residue left after the 2 per cent HCl extraction was multiplied by the weight of this residue to obtain the cellulose and lignin content in the original 6 grams of material.

TABLE I

COMPOSITION OF OVEN DRIED SUGAR CANE TRASH

Chemical Constituents	Sample No. 1 POJ-2714 per cent	Sample No. 2 S. C. 12-4 per cent
Ether soluble Fraction	2.34	1.85
Cold Water Soluble Organic Matter	4.42	1.92
Hot Water Soluble Organic Matter	2.17	1.56
Alcohol Soluble Fraction	.56	1.25
Hemicelluloses	25.33	26.32
Celluloses	29.71	32.85
Lignin (nitrogen & ash free)	11.53	16.06
Water insoluble protein	2.00	2.25
Total Ash	12.79	6.30
Totals	90.85	90.3

The total nitrogen contents by the Kjeldahl method were 0.59 per cent and 0.64 per cent for samples 1 and 2, respectively. The total carbon contained in the first sample was 40.3 per cent as determined by a wet method (**23**) using $KMnO_4$ as the oxidizing agent. The pentosan content of the same sample was 25.21 per cent as determined by furfural distillation with 12 per cent HCl and precipitation with phloroglucinol. Total carbon and pentosans were not determined on the second sample. There were no reducing sugars in the water extracts of either sample of trash.

DECOMPOSITION OF SUGAR-CANE TRASH

Trash sample No. 2 (SC–12–4) was used in this experiment. It was chopped in pieces about ½ inch in size. Twenty grams portions in each of 12 one-liter flasks were inoculated with 1 cc. of soil infusion (10 grams of soil to 100 cc. of tap water). Enough water was added

to give composts containing 66, 80 and 88 per cent of water. The treatments were as follows:

1 and 2----------66 per cent water
3 and 4----------66 per cent water + 1 gm. $(NH_4)_2SO_4$
5 and 6----------80 per cent water
7 and 8----------80 per cent water + 1 gm. $(NH_4)_2SO_4$
9 and 10----------88 per cent water
11 and 12----------88 per cent water + 1 gm. $(NH_4)_2SO_4$

One set was incubated for thirty days at 28°C and a second set for sixty days before analyses were made. Tests for moisture, nitrates, ammonia and total nitrogen were made on the wet decomposed material. Nitrates were determined by the phenoldisulphonic acid method. Ammonia was extracted with normal KCl and determined by distillation with magnesium oxide. Total nitrogen was determined by the Kjeldahl method.

The analysis of the organic constituents was performed on 6-gram portions of the material after drying at 40°C. The procedure previously described was followed with one exception; no cold water treatment was given.

TABLE II

DRY WEIGHT LOSSES OF SUGAR CANE TRASH COMPOSTED FOR 30 AND 60 DAYS WITH OR WITHOUT ADDITIONAL INORGANIC NITROGEN

Days	Original Material	66 per cent Water		80 per cent Water		88 per cent Water	
		No nitrogen added	Nitrogen added*	No nitrogen added	Nitrogen added*	No nitrogen added	Nitrogen added*
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
30	20	17.9	14.9	17.4	15.9	18.2	14.8
60	20	16.4	14.9	16.4	13.6	14.8	13.2

* Figures represent dry weight of residual material plus residual dry weight of $(NH_4)_2SO_4$ added.

The information given in terms of dry weight losses is of limited value unless we consider the fate of the different groups which constitute the sugar-cane trash complex.

TABLE III

COMPOSITION OF SUGAR CANE TRASH COMPOSTED FOR 30 DAYS WITH OR WITHOUT ADDITIONAL INORGANIC NITROGEN

Chemical Constituents (1)	Original Material	66 per cent Water		80 per cent Water		88 per cent Water	
		No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Ether soluble fraction	1.85	1.08	1.57	1.05	1.18	0.89	1.04
Hot and cold water soluble organic matter (2)	3.48	3.39	7.48	4.14	6.68	2.94	5.59
Alcohol soluble fraction	1.24	1.37	2.29	1.55	2.39	1.45	2.34
Hemicelluloses	26.32	24.17	20.32	24.19	20.86	23.91	20.32
Celluloses	32.85	31.33	23.49	30.90	23.26	32.29	22.65
Lignin (nitrogen and ash free)	16.06	18.10	20.31	19.35	21.19	18.33	21.22
Water insoluble protein	2.25	3.06	7.44	3.56	5.94	3.81	9.44
Nitrogen as ammonia	0.00	0.00	0.83	0.00	0.75	0.00	0.75
Total ash	6.30	6.86	9.29	7.40	9.64	7.12	9.16
Totals	90.35	89.36	93.02	92.14	91.89	90.74	92.53

TABLE IV

COMPOSITION OF SUGAR CANE TRASH COMPOSTED FOR 60 DAYS WITH OR WITHOUT ADDITIONAL INORGANIC NITROGEN

Chemical Constituents (1)	Original Material	66 per cent Water		80 per cent Water		88 per cent Water	
		No nitrogen added	Nitrogen added*	No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Ether soluble fraction	1.85	1.22	1.51	1.12	1.30	0.86	1.18
Hot and cold water soluble organic matter (2)	3.48	3.80	7.30	3.48	6.69	3.88	6.57
Alcohol soluble fraction	1.24	1.02	1.88	1.02	1.80	1.14	1.63
Hemicelluloses	26.32	24.35	19.33	24.24	18.78	22.29	19.39
Celluloses	32.85	27.68	17.49	30.64	17.61	27.65	18.12
Lignin (nitrogen and ash free)	16.06	19.13	22.41	19.44	22.81	19.88	24.41
Water insoluble protein	2.25	5.13	8.63	4.81	10.19	5.81	11.75
Nitrogen as ammonia	0.00	0.00	0.70	0.00	0.79	0.69	0.77
Total ash	6.30	8.52	9.78	7.76	10.42	8.24	10.94
Totals	90.35	90.85	89.03	92.51	90.39	89.75	94.66

(1)—All calculations on residual material dried at 100° C.
(2)—Water soluble organic nitrogen included.

Results as expressed in Tables III and IV are of a relative value; since the dry weight of the original material does not remain constant during the decomposition processes. Results in terms of actual weight as expressed in Tables V and VI give a much better information of the fate of the chemical constituents during the decomposition processes.

TABLE V

TOTAL CONCENTRATION OF THE CHEMICAL CONSTITUENTS OF SUGAR CANE TRASH COMPOSTED FOR 30 DAYS WITH OR WITHOUT ADDITIONAL NITROGEN

Chemical Constituents	Original Material (20 gms)	66 per cent Water		80 per cent Water		88 per cent Water	
		No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added*	No nitrogen added	Nitrogen added
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Ether soluble fraction	0.370	0.193	0.234	0.183	0.187	0.162	0.154
Hot and cold water soluble organic matter	0.696	0.608	1.115	0.720	1.062	0.535	0.828
Alcohol soluble fraction	0.248	0.245	0.341	0.270	0.380	0.264	0.346
Hemicelluloses	5.264	4.326	3.028	4.209	3.317	4.352	3.007
Celluloses	6.570	5.608	3.500	5.377	3.698	5.877	3.352
Lignin (nitrogen and ash free)	3.212	3.240	3.026	3.367	3.369	3.336	3.141
Water insoluble protein	0.450	0.548	1.109	0.619	0.944	0.693	1.397
Nitrogen as ammonia	0.000	0.000	0.124	0.000	0.119	0.000	0.111
Total ash	1.260	1.228	1.384	1.288	1.533	1.296	1.356
Totals	18.070	15.996	13.861	16.033	14.609	16.515	13.692

TABLE VI

TOTAL CONCENTRATION OF THE CHEMICAL CONSTITUENTS OF SUGAR CANE TRASH COMPOSTED FOR 60 DAYS WITH OR WITHOUT ADDITIONAL NITROGEN

Chemical Constituents	Original Material (20 gms)	66 per cent Water		80 per cent Water		88 per cent Water	
		No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added	No nitrogen added	Nitrogen added
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Ether soluble fraction	0.370	0.200	0.225	0.184	0.177	0.127	0.156
Hot and cold water soluble organic matter	0.696	0.623	1.088	0.571	0.910	0.574	0.867
Alcohol soluble fraction	0.248	0.167	0.280	0.167	.245	0.169	0.202
Hemicelluloses	5.264	3.993	2.880	3.975	2.554	3.299	2.558
Celluloses	6.570	4.540	2.606	5.025	2.395	4.092	2.391
Lignin (nitrogen and ash free)	3.212	3.137	3.339	3.188	3.102	2.942	3.222
Water insoluble protein	.450	.841	1.286	.789	1.386	.860	1.551
Nitrogen as ammonia	0.000	0.000	0.104	0.000	0.107	0.000	0.102
Total ash	1.260	1.397	1.457	1.273	1.417	1.220	1.444
Totals	18.070	14.898	13.265	15.172	12.293	13.283	12.493

Tables VII and VIII give the per cent of each of the original groups left after composting for thirty and sixty days.

TABLE VII

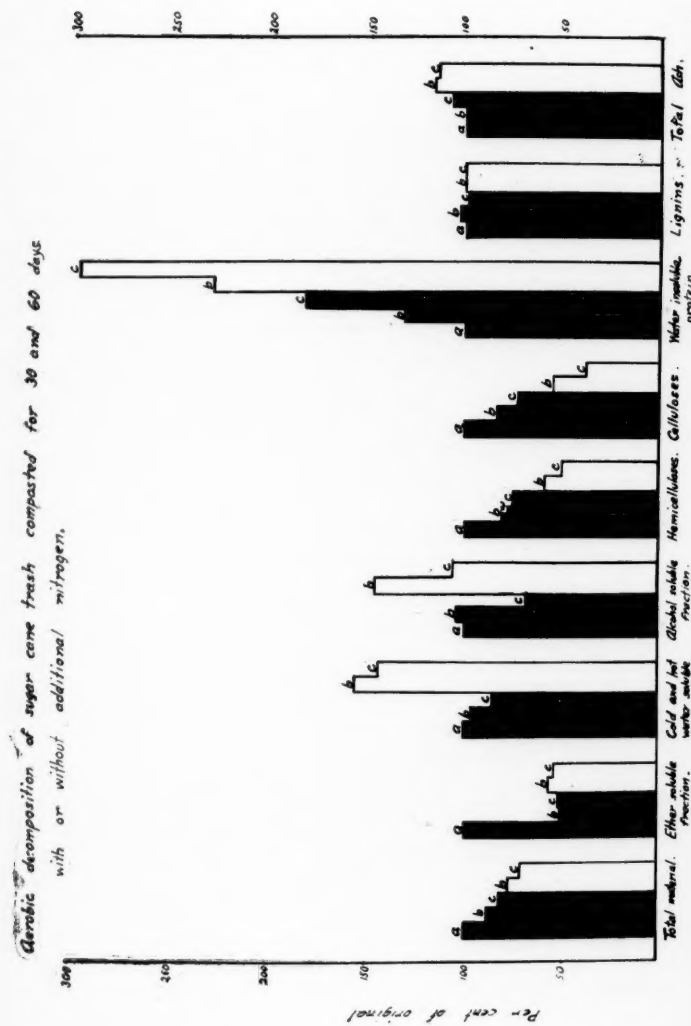
RESIDUAL MATERIAL OF THE VARIOUS CHEMICAL CONSTITUENTS OF SUGAR CANE TRASH COMPOSTED WITHOUT THE ADDITION OF NITROGEN

	Original Material	66 per cent Water		80 per cent Water		88 per cent Water	
		30 days	60 days	30 days	60 days	30 days	60 days
	gm.	Per cent of original	Per cent of original	Per cent of original	Per cent of original	Per cent of original	Per cent of original
Total dry material	20.00	89.50	82.00	87.00	82.00	91.00	74.00
Ether soluble fraction	0.370	52.16	54.05	49.46	49.73	43.79	34.32
Cold and hot water soluble organic matter	0.696	87.36	89.51	103.45	82.04	76.87	82.47
Alcohol soluble fraction	0.248	98.79	67.34	108.87	67.34	106.45	68.15
Hemicelluloses	5.264	82.18	75.85	79.96	75.51	82.67	62.67
Celluloses	6.570	85.36	69.10	81.84	76.48	89.45	62.28
Lignins (nitrogen and ash free)	3.212	100.87	97.67	104.83	99.25	103.86	91.59
Water insoluble protein	0.450	121.78	186.89	137.56	175.33	154.00	191.11
Total ash	1.260	97.46	110.87	102.22	101.03	102.86	96.83

TABLE VIII

RESIDUAL MATERIAL OF THE VARIOUS CHEMICAL CONSTITUENTS OF SUGAR CANE TRASH COMPOSTED WITH THE ADDITION OF NITROGEN

	Original Material	66 per cent Water		80 per cent Water		88 per cent Water	
		30 days	60 days	30 days	60 days	30 days	60 days
	gm.	Per cent of original	Per cent of original	Per cent of original	Per cent of original	Per cent of original	Per cent of original
Total dry material	20.00	74.50	74.50	79.50	68.00	74.00	66.00
Ether soluble fraction	0.370	63.24	60.81	50.54	47.84	41.62	42.16
Cold and hot water soluble organic matter	0.696	160.21	156.32	152.59	130.75	118.97	124.57
Alcohol soluble fraction	0.248	137.50	112.90	153.23	98.79	139.52	81.45
Hemicelluloses	5.264	57.52	54.71	63.01	48.52	57.12	48.59
Celluloses	6.570	53.27	39.67	56.29	36.45	51.02	36.39
Lignins (nitrogen and ash free)	3.212	94.21	103.95	104.89	96.58	97.79	100.31
Water insoluble protein	0.450	246.44	285.78	269.78	308.00	310.44	344.67
Total ash	1.260	109.84	115.63	121.67	112.46	107.62	114.60


Aerobic decomposition of sugar cane trash composted for 30 and 60 days with or without additional nitrogen.
Per cent of original
300
250
200
150
100
50
Total material.
Ether soluble fraction.
Cold and hot water soluble organic matter.
Alcohol soluble fraction.
Hemicelluloses.
Cellulases.
Water insoluble protein.
Lignins.
Total det.
a. Original material; b. Left after 30 days; c. Left after 60 days.
Black area - no nitrogen added. White area - nitrogen added.

The rate of conversion of the available forms of nitrogen into less available forms of nitrogen constituting the cells of microorganisms active in the decomposition processes is shown in Tables IX and X

TABLE IX

"NITROGEN TRANSFORMATION IN THE DECOMPOSITION OF SUGAR CANE TRASH"

(In per cent of total residual material)

Form of Nitrogen	No Nitrogen Added							Nitrogen Added						
		66% Water		80% Water		88% Water			66% Water		80% Water		88% Water	
	0 days	30 days	60 days	30 days	60 days	30 days	60 days	0 days	30 days	60 days	30 days	60 days	30 days	60 days
Total nitrogen	.64	.68	.92	.70	.86	.76	1.06	1.70	2.25	2.25	2.08	2.46	2.30	2.67
Nitrogen as ammonia	0	0	0	0	0	0	0	1.06	.83	.70	.75	.79	.75	.77
Soluble in hot and cold water	.28	.12	.10	.13	.09	.15	.13	....	.93	.87	1.07	.83	.79	.79
Hydrolyzable by 2 per cent HCl	.12	.19	.26	.24	.26	.23	.38	....	.43	.61	.47	.70	.52	.73
"Humin" nitrogen, not acted by autoclaving with 6 per cent H_2SO_4	.22	.22	.29	.25	.28	.26	.36	....	.37	.44	.37	.49	.42	.49

TABLE X

TOTAL CONCENTRATION OF THE NITROGEN TRANSFORMATION OF SUGAR CANE TRASH DECOMPOSING FOR 30 AND 60 DAYS AT DIFFERENT MOISTURES, WITH AND WITHOUT ADDITIONAL NITROGEN

Form of Nitrogen	No Nitrogen Added							Nitrogen Added						
	Original material 20 gms.	66% H_2O		80% H_2O		88% H_2O		Original material 20 gms.	66% H_2O		80% H_2O		88% H_2O	
		30 days	60 days	30 days	60 days	30 days	60 days		30 days	60 days	30 days	60 days	30 days	60 days
	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.
Total Nitrogen	128	122	151	122	141	138	157	340	335	335	331	335	340	352
Nitrogen as ammonia	0	0	0	0	0	0	0	212	124	104	119	107	111	102
Soluble in cold and hot water	56	21	16	23	15	27	22	....	138	130	170	113	117	104
Hydrolyzable by 2 per cent HCl	24	34	33	42	43	42	34	....	64	91	75	95	77	96
"Humin" nitrogen, not acted by autoclaving with 6 per cent H_2SO_4	44	39	48	44	46	47	38	....	55	66	59	67	62	65

DECOMPOSITION OF CANE TRASH AS MEASURED BY THE EVOLUTION OF CARBON DIOXIDE

The decomposition of cane trash as measured by the evolution of carbon dioxide with or without the addition of minerals was studied in three different soil types brought from Puerto Rico by special permission of the United States Quarantine Board. These soils were among the first ones classified in the Soil Survey of Puerto Rico

which started in the fall of 1928 under the supervision of the United States Bureau of Soils. The types are:

1. Río Piedras clay. This type belongs to the Río Piedras series, deep phase. It is typically developed on the hills of the Puerto Rico Insular Experiment Station. The sample was taken at Km. 2.25 Leprocomio road, Trujillo. This soil is used for sugar cane and other crops.
2. Bayamón clay loam. This type belongs to the Bayamón series. It is strongly acid. The sample was taken at Km. 2.2, Sanatorium Road, Río Piedras. This soil is mainly used for citrus, sugar cane and other crops.
3. Múcara clay. It has the characteristics of Río Piedras clay but is higher in organic matter content. The sample was taken at Km. 2.8 Carolina–Juncos Road. This soil is used for sugar cane and other crops.

The Río Piedras clay and Bayamón clay loam are types representing poor sugar-cane soil. The Múcara clay represents a better sugar-cane soil.

All the soil samples were taken to a depth of six inches in a suitable place in the field. They were air-dried and sifted through a 2mm. sieve. The soils were free from carbonates.

To a duplicate set of seven 300 cc. Florence flasks the following materials were added:

(1) Trash.
(2) Trash + $(NH_4)_2HPO_4$ + K_2HPO_4.
(3) Trash + $NaNO_3$ + K_2HPO_4.
(4) Soil.
(5) Soil + trash.
(6) Soil + trash + $(NH_4)_2HPO_4$ + K_2HPO_4.
(7) Soil + trash + $NaNO_3$ + K_2HPO_4.

The first three treatments were inoculated with 1 c. c. soil infusion prepared by adding 100 c.c. of tap water to 10 grams of a rich soil (Sassafras sandy loam). The amount of trash added represented 5 grams of the dry material. Ground trash sample No. 1 (POJ-2714) was used. It was kept at optimum moisture by adding 200 per cent of its own dry weight as water.

The amount of soil used represented 100 grams of dry soil. Water was added to bring the moisture content up to 25 per cent. The equivalent of 42.3 mgm. of nitrogen and 100 mgm. of K_2HPO_4 were added as mineral sources. The complete set was connected to a carbon dioxide apparatus, as described by Waksman and Starkey. (**24**.)

The carbon dioxide given off was collected in one-sixth normal $Ba(OH_2)$. The excess of barium hydroxide was titrated back with one-sixth normal oxalic acid to determine the carbon dioxide absorbed, using phenolphthalein as an indicater. The experiment lasted 28 days. The system was aerated daily for four hours. Titrations were made every day during the first week and every other day, afterwards. Analyses for pH, nitrate and ammonia were made at the end. The quinhydrone electrode was used for pH determinations. Nitrates were determined by the phenoldisulphonic acid method. The ammonia was collected in 300 c. c. Florence flasks after consecutive leachings with 100, 50, and 50 c. c. portions of normal KCl and 50 c. c. water. The ammonia was distilled over after neutralizing with magnesium oxide.

TABLE XI

EVOLUTION OF CARBON DIOXIDE FROM CANE TRASH ADDED TO PUERTO RICO SOILS WITH OR WITHOUT THE ADDITION OF MINERALS

Treatments	After 28 days			
	Total mgm. C as CO_2	pH	Nitrate mgm. of nitrogen in flask	Ammonia mgm. of nitrogen in flask
Trash	124	7.1	None	None
Trash + $(NH_4)_2HPO_4$ + K_2HPO_4	445	6.6	None	16.0
Trash + $NaNO_3$ + K_2HPO_4	330	9.0	15.3	None
Múcara clay	37	6.8	9.2	1.8
Múcara clay + trash	351	6.7	None	None
Múcara clay + trash + $(NH_4)_2HPO_4$ + K_2HPO_4	441	7.0	1.8	17.7
Múcara clay + trash + $NaNO_3$ + K_2HPO_4	452	7.2	12.5	None
Río Piedras clay	27	6.7	5.7	7.4
Río Piedras clay + trash	303	6.4	None	None
Río Piedras clay + trash + $(NH_4)_2HPO_4$ + K_2HPO_4	267	6.6	None	28.6
Río Piedras clay + trash + $NaNO_3$ + K_2HPO_4	292	7.4	None	11.6
Bayamón clay loam	27	5.0	2.4	4.0
Bayamón clay + trash	225	5.0	None	None
Bayamón clay + trash + $(NH_4)_2HPO_4$ + K_2HPO_4	260	5.5	None	32.0
Bayamón clay + trash + $NaNO_3$ + K_2HPO_4	317	5.3	20.1	None

INFLUENCE OF SOIL TREATMENT UPON THE MICROBIAL POPULATION

In the previous treatment given to the Puerto Rico soils the number of fungi, bacteria and actinomyces were determined after fifteen and thirty days by the plate method. Peptone-Glucose acid Agar (**21**) was the medium used for fungi. Sodium Albuminate Agar (**22**) was the medium used for bacteria and actinomyces. Five plates were poured for each treatment. The plates were incubated at 28° C. Fungi were counted after three days. Bacteria and actinomyces were counted after ten days in the same plate.

TABLE XII

ABUNDANCE OF MICROORGANISMS IN SOILS KEPT AT OPTIMUM MOISTURE

Treatment	Number of Fungi X 1,000							
	Río Piedras Clay		Bayamón Clay Loam		Múcara Clay		Toa Silt Loam	
	15 days	30 days	15 days	30 days	15 days	30 days	15 days	30 days
Soil alone	27.0	29.0	134.0	40	46	28	40	42
Soil + $CaCO_3$	70	28	36	39	31	22	28	35
Soil + dried blood	433	220	447	346	216	236	290	496
Soil + $(NH_4)_2SO_4$	50	28	70	139	45	26	43	58
Soil + $(NH_4)_2SO_4$ + $CaCO_3$	57	15	90	62	40	24	25	11
Soil + cane trash	700	103	697	856	236	180	206	286
Soil + cane trash + $(NH_4)_2HPO_4$	933	230	837	836	560	166	510	454

Treatment	Number of Bacteria X 100,000							
	Río Piedras Clay		Bayamón Clay Loam		Múcara Clay		Toa Silt Loam	
	15 days	30 days	15 days	30 days	15 days	30 days	15 days	30 days
Soil alone	63	170	227	69	34	83	69	351
Soil + $CaCO_3$	180	261	134	89	80	146	75	281
Soil + dried blood	163	354	1,130	250	24	334	128	864
Soil + $(NH_4)_2SO_4$	91	208	140	82	51	54	61	672
Soil + $(NH_4)_2SO_4$ + $CaCO_3$	180	58	158	93	42	84	99	530
Soil + cane trash	490	222	1,246	640	280	100	96	468
Soil + cane trash + $(NH_4)_2HPO_4$	700	236	1,695	235	264	448	174	748

Treatment	Number of Actinomyces X 100,000							
	Río Piedras Clay		Bayamón Clay Loam		Múcara Clay		Toa Silt Loam	
	15 days	30 days	15 days	30 days	15 days	30 days	15 days	30 days
Soil alone	29	40	48	20	8	46	17	32
Soil + $CaCO_3$	61	52	14	13	26	29	23	26
Soil + dried blood	360	154	110	150	224	206	220	306
Soil + $(NH_4)_2SO_4$	46	62	6	8	34	42	29	47
Soil + $(NH_4)_2SO_4$ + $CaCO_3$	68	24	14	27	16	17	27	33
Soil + cane trash	267	88	47	100	100	20	60	96
Soil + cane trash + $(NH_4)_2HPO_4$	363	144	210	85	116	152	116	112

DISCUSSION OF RESULTS

The two samples of trash differ considerably in composition, as shown in Table I. This may be due to differences in the varieties, to age effects or to the methods of sampling the materials. S.C. 12-4 trash was taken as dead leaves from the lower part of the stems. P.O.J. 2714 trash was gathered from soil surface around the cane. Waksman and Tenney (**26**) have shown that the composition of plant remains is different with different plants and the same plant at different stages of growth. The younger the plant and the less mature it is the greater will be the content of readily decomposable material.

The S.C. 12–4 has 2.81 per cent less water soluble organic matter, 1 per cent more hemicelluloses, 3.14 per cent more cellulose, 4.53 per cent more lignin and 6.49 per cent less ash than the P.O.J. 2714. The furfural determination shows that almost all the hemicelluloses of the P.O.J. 2714 were pentosans.

If both samples of trash were placed under similar environmental conditions, it would seem likely that the composition of the variety P.O.J. 2714 would be such as to result in its more rapid decomposition.

Celluloses and hemicelluloses add 55.24 per cent for P.O.J. 2714 and 59.17 per cent for S.C. 12(4). It is very important, therefore, to understand the role of soil microorganisms in decomposing such complexes for energy purposes. Organisms capable of decomposing celluloses under aerobic conditions are found among various groups of fungi, among the actinomyces and among certain specific bacteria. However, under anaerobic conditions, the fungi and actinomyces do not thrive and bacteria alone are entirely concerned in the process. Many fungi are capable of decomposing hemicelluloses. Certain specific bacteria and lower animals are also capable of assimilating hemicelluloses.

Certain hemicelluloses are more readily decomposed than others. The degree of decomposition varies with the nature of the plant and the type of hemicelloluse. Pentosans are more readily decomposed than hexosans.

Table 2 gives the dry weight losses of sugar-cane trash composted for thirty and sixty days with or without additional inorganic nitrogen. The trash was inoculated with soil infusion to provide for the presence of the soil variable microflora and microfauna. No deduction was made for the dry weight increase due to the addition of $(NH_4)_2SO_4$ because of the complicated nature of the chemical changes affecting this salt during microbial activities.

In the compost material containing 88 per cent water, evil smelling substances, seemed to indicate that some anaerobic decomposition was going on. Such evil smelling substances were not noticed in the other treatments. The presence of 88 per cent moisture represents the addition of 733 per cent of water to the dry material. The degree of saturation seems to be too high for the free circulation of air. As conditions were partly anaerobic, it is advisable, not to compare the results obtained in the 88 per cent H_2O treatment with those obtained in the 66 and 80 per cent H_2O treatments whose average value in this discussion is taken to represent aerobic decom-

position. The nature of the processes involved would be different in both cases.

It is obvious, that the information obtained from losses of dry weight, is of a very limited value. The individual groups constituting the trash complex are not affected at the same rate. Some groups tend to increase; others tend to decrease and others tend to remain more or less constant. The increase in some of the groups compensates the decrease in others and therefore an appreciable change of the total dry material is not noticed.

The ether and alcohol soluble fractions constitute a heterogeneous group of complexes such as oils, waxes, resins, tannins, terpenes, alkaloids, etc. As the percentage of these two groups in sugar-cane trash is quite small, namely around 3 per cent, not much stress is to be laid on their fate during the processes of decomposition. It seems, however, that about 50 per cent of the ether soluble fraction is of such nature as to decompose during the first thirty days. The rest seems to be more resistant to decomposition; even with the addition of nitrogen.

The celluloses and hemicelluloses disappeared more rapidly than could be accounted for by the decrease in total dry weight. The decrease in weight due to their decomposition is balanced by the accumulation of proteins. Their disappearance may be due to actual loss of carbon as carbon dioxide or to transformation into the new complexes synthesized by the microorganisms. It must be remembered that in such a biological process as, composting sugar-cane trash, decomposition and synthesis take place side by side. The increase in water insoluble protein corroborates the synthesis of new protein cell material.

The lignin fraction remains more or less constant. Waksman and Tenney (**28**) studied the decomposition of composted rye straw under aerobic conditions for a period of 386 days. They found that the decomposition of celluloses and hemicelluloses accounted for most of the decomposed plant materials. This was accompanied by an increase of water insoluble protein and lignins.

Further studies on sugar-cane trash decomposition for a period over sixty days would give more evidence of the fate of the lignin fraction. It also will show up to what limit the celluloses and hemicelluloses become resistant to decomposition.

The addition of nitrogen in both, aerobic and partly anaerobic conditions, activated the heterotrophic organisms in decomposing more celluloses and hemicelluloses. This was accompanied by a

larger increase of water insoluble protein and water soluble organic matter.

The total ash content remained more or less constant in all the treatments to which nitrogen was not added. The increase in ash content due to the addition of one gram of $(NH_4)_2SO_4$ varied only from 0.06 to 0.25 gram. This supports the statement previously made:

"No deduction was made in Table 2 for the dry weight increase due to the addition of $(NH_4)_2SO_4$ because of the complicated nature of the chemical changes affecting this salt during microbial activities."

Tables IX and X show that with the progress of decomposition there was a decrease of the nitrogen soluble in cold water and a corresponding increase in the nitrogen hydrolizable by dilute hydrochloric acid and in the more resistant or so-called "humin" nitrogen. This points, once more, to the building up by microorganisms of proteins and other complex organic nitrogenous compounds.

The 212 milligrams of nitrogen added to the compost was in excess to that required by the active microorganisms. Under aerobic conditions, after thirty days, an average of 122 milligrams of nitrogen as ammonia was recovered. After sixty days, 106 milligrams were thus recovered. The ratio of available nitrogen used to hemicelluloses and celluloses decomposed was as follows:

	66 per cent water	80 per cent water	88 per cent water
30 days	1:39	1:28	1:38
60 days	1:28	1:39	1:22

Practically all the nitrogen was recovered in the residual material. This shows that there was no loss of nitrogen either by volatization or reduction processes. These results throw further light upon the problem of synthesis of new protein material as a result of the activities of the microorganisms which bring about the decomposition of the celluloses and hemicelluloses. In the absence of additional nitrogen, the increase in the amount of water insoluble protein took place at the expense of the water soluble simple nitrogenous compounds. Some of the nitrogenous substances synthesized by the microorganisms, are only slowly available sources of nitrogen for soil microorganisms, otherwise the celluloses and hemicelluloses would have undergone a much more rapid decomposition. The slight increase of the total nitrogen fraction in the compost to which no

nitrogen was added may be due to nitrogen fixation. Energy for the nitrogen fixers may have been taken from the disintegration products resulting from the decomposition of celluloses and hemicelluloses.

At the end of the experimental periods the trash to which nitrogen was added was more brittle and readily crumbled between the fingers. Probably such a material would not interfere with the plowing operation. The decomposed material resembled soil humus in color.

Further studies extended over longer periods of time on decomposition of cane trash in the presence of available minerals, especially nitrogen and phosphorus, should give information on how to use the minerals in the most economical way.

Carbon dioxide as an index of soil fertility has been discussed by Waksman and Starkey (**24**).

Results given in Table XI indicate that the Múcara clay liberated the greatest amount of carbon dioxide in all the treatments. The rapidity of trash decomposition depends on the rate by which soil microorganisms utilize available minerals present, especially nitrogen. It seems that the Múcara clay supplies minerals at a faster rate than the two other soils. The Bayamón clay loam seems to have the lowest mineral spuplying power. From field returns it can be said that the Múcara clay is a better sugar-cane soil.

Carbon dioxide evolution in the Río Piedras clay was not stimulated by the addition of minerals. Probably some physical factor must be responsible for repressing microbial activity. May be this soil, at optimum moisture conditions, would behave differently.

Microorganic activity was repressed when $NaNO_3$ was added to the trash in the absence of soil. Probably this was due to high alkalinity (pH 9.0) or to toxicity of the sodium or nitrate ion. The buffer effect of the soil seems to check such effect.

No definite explanation can be given for the reduction of nitrates to ammonia when $NaNO_2$ and trash were added to the Río Piedras clay. This might have been due to an involuntary addition of $(NH_4)_2HPO_4$ for $NaNO_3$; but the increase to (pH 7.4) seems to indicate that there was not such an error.

Fungi, bacteria and actimomyces were most abundant when dried blood and cane trash were added. The organic matter in the form of those materials offered a good energy source for the heterotrophic soil organisms which develop well in the plate method.

When straw is added to the soil, the microorganisms decomposing

celluloses and hemicelluloses use the available nitrogen present in the soil, up to a certain limit. It seems dangerous to leave trash on a nitrogen starving soil planted to cane. The ratio between the amount of cellulose decomposed and the amount of nitrogen assimilated is about 30:1 in the case of fungi and aerobic bacteria. However, in the soil, where the cells of microorganisms freshly synthesized are constantly decomposed by other organisms, the ratio is 50–60:1 (**25**). In other words; for every unit of nitrogen that can become available in the soil in a definite period of time, about 50 to 60 units of cellulose will be decomposed. Such a ratio has not been experimentally established for hemicelluloses; but it is believed that an identical ratio prevails.

To hasten the decomposition of sugar-cane trash in the sugar-cane fields it is evident that available nitrogen must be given to the soil microorganisms. Nitrogen is supplied with great cost to most crops and especially so, to sugar-cane. It is a standard practice in Hawaii, Java, and Puerto Rico to apply heavy applications of inorganic fertilizers to fields of sugar cane. Hawaii leads with applications of 600 to 1,000 pounds of a complete fertilizer per acre followed by 400 to 600 pounds of sodium nitrate or ammonium sulphate. Puerto Rico is approaching Hawaii and applies 400 to 800 pounds of a complete fertilizer followed by 300 to 400 pounds of ammonium sulphate. Java growers are strong supporters of ammonium sulphate alone. They apply from 100 to 1,200 pounds per acre. Cuba is also using large amounts of fertilizers.

In the tropics, especially in the regions of high rainfall, there are great losses of available nitrogen in the run-off and percolating waters. Sugar-cane trash would serve as a store of available nitrogen. The nitrogen deposited as proteins in the cells of soil microorganisms would not leach so readily. Further microbial activity would convert the stored nitrogen into forms available for the sugar-cane plant.

In 1927, Albrecht (**2**) reports:

> "Some recent work by the Oregon Experiment Station indicates that artificial manure can be made successfully with ten pounds of nitrogen per ton of straw. It is customary in England to add about fourteen parts of nitrogen per ton of straw."

The average nitrogen per acre added to the sugar-cane fields of Hawaii and Puerto Rico is about 180 and 148 pounds, respectively. The addition of a part of this nitrogen to the sugar-cane trash would hasten its decomposition in the soil. Such addition of nitrogen to

the trash would tend to improve the trash physical condition for the plowing operation.

A farmer in the United States adding every year an average of 2,000 pounds of organic matter per acre is doing quite well. Such an average for the tropics would be too low because the decomposition of organic matter is greatly hastened by optimum climatic conditions.

Considering that thirty tons of cane per acre gives about ten tons of green straw and assuming that the green straw contains about 75 per cent of water; 5,000 pounds of dry material would remain in the soil. Deducting for ash, 10 per cent of the dry weight; 4,500 pounds of organic matter will be left for enriching the soil supplies of organic matter.

Nitrogen could be supplied, as a means of hastening trash decomposition, by a quick growing leguminous plant. Nitrogen could also be supplied by scattering over the trash part of the fertilizer added to the sugar-cane plant. Perhaps, it would be practical to adopt a wet spraying method.

The economic advisability of applying a source of available minerals, especially nitrogen, as a means of hastening trash decomposition must be established by adequate experimentation. The questions to be answered are: What form of nitrogen is the most adequate? What amount of nitrogen must be added to make this practice a paying proposition? How should this nitrogen be added? How long will it take for the nitrogen transformed into the complex proteins of microbial protoplasm to become available for the use of the plant?

SUMMARY

The decomposition of sugar-cane trash on the basis of its chemical composition has been studied when kept at different moisture contents with or without the addition of inorganic nitrogen for a period of thirty and sixty days at 28°C. Results lead to the following conclusions:

(1) The addition of inorganic nitrogen to the composted trash hastened the decomposition processes.
(2) The ether and alcohol fractions account for a very slight portion of the total organic matter decomposition.
(3) The decomposition of the celluloses and hemicelluloses account for most of the decomposed organic matter. As such groups represent a good source of energy for the heterotrophic organisms their disappearance may be due to actual loss of carbon dioxide or to transformations

into the new complexes synthesized by the microorganisms. This synthesis is further proven by an accumulation in crude protein and an increase in the water soluble matter.

(4) The lignin and ash fractions remain more or less constant.

(5) Practically all the nitrogen present and added was recovered in the residual material. There was no loss, therefore, of nitrogen either by volatilization or reduction processes. The slight increase of the total nitrogen fraction in the compost to which no nitrogen was added may be due to nitrogen fixation. Energy for the nitrogen fixers may have been taken from the disintegration products resulting from the decomposition of celluloses and hemicelluloses.

(6) The addition of nitrogen improved the physical conditions of the trash. It was more brittle and readily crumbled between the fingers.

(7) Addition of trash to three soil types from Puerto Rico increased the rate of carbon dioxide seven to nine times.

(8) Influence of soil treatment upon the microbial population showed an increase in the numbers of fungi, bacteria and actinomyces when dried blood or sugar-cane trash was added to the soils.

ADDENDA

After this manuscript was sent to press the author received a reprint of Owen's and Denson's (31) recent work at Louisiana on "The effect of plowing under cane trash upon the available nitrogen of the soil." The investigation was outlined in the following heads:

1. "The various organic constituents of cane trash.
2. The rate of decomposition of cane trash and its various fractions as measured by the evolution of carbon dioxide.
3. The effect of age upon the depressing action of cane trash upon soil nitrates.
4. The influence of cane trash upon the soil microflora.
5. The utilization of forms of nitrogen other than nitrates for the decomposition of cane trash in soils.
6. The cycle of nitrogen incorporation and release from microbial protoplasm.
7. The influence of cane trash upon plant growth.
8. The effect of turned under cane trash upon moisture retention in the soil.
9. The agronomic phases of plowing under cane trash."

The authors conclusions were:

1. "The addition of fresh cane trash to soils containing nitrates causes a very rapid transformation of the nitrogen into organic forms.

2. The depressing effect of cane trash upon nitrates, diminishes at a fairly constant rate when this crop residue is in contact with the soil, and under ordinary conditions it has perhaps lost most of its pernicious effects at the time the fertilizer is applied to cane.
3. The addition of fresh trash retards appreciably the rate of growth of corn plants, but the incorporation of trash which has been partially buried for several months, increased the yields and the initial rate of growth.
4. The addition of cane trash to soils increase their water holding capacity, and decreases their rate of drying, so that in seasons of drought this may be quite a factor in conserving the moisture of the soil.
5. The addition of cane trash to soils results in appreciable gains of total nitrogen, indicating the stimulation of the nitrogen fixing bacteria by the products resulting from the decomposition of organic matter incorporated in the soil.
6. The fact that field experiments over a period of several years at this Station, have shown no decrease in crop yields from the practice of turning under cane trash it would appear that the nitrate nitrogen immobilized by the presence of the organic matter, is in excess of the immediate requirements of the growing crop. This would make the practice of turning under trash, consistent with the necessity of conserving the surplus available nitrogen in the soil.
7. Whether the continued practice of incorporating such large quantities of organic matter with a C : N ratio of approximately 1 : 40 would tend to so increase the accumulation of the more resistant constituent lignin, as to unfavorably affect the composition, and the productiveness of a soil is a question, the importance of which warrants further study."

REFERENCES

1. **Agee, H. P.** The implements of the industry. H. S. P. A. Expt. Sta. Agr. Chem. Ser. Bul. 44: 1–84. 1914.
2. **Albrecht, Wm. A.** Artificial manure production on the farm. Missouri Agric. Exp. Sta. Bul. 258: 1–20. 1927.
3. **Alincastre, C.** Cane burning before cutting. Sugar News 7: 272–285. 1926.
4. **Bonazzi, A.** Sugar-cane trash as manure La. Planter 75(21): 410–412. 1925.
5. **Cross, Wm. E.** Experiment in planting sugar cane without burning the trash. Rev. Indus. Agr. Tucuman, 18: 116–123, 1928.
6. **Deerr, Noel.** Cane Sugar, .p 101–102. Norman Rodgers, London. 1921.

7. **De Turk, E. E.** Organic matter supplied in crop residues. Journal Amer. Soc. Agron. 19: 5. 1926.
8. **Fernández García, R.** Preliminary studies of the soil organic matter. Puerto Rico Insular Expt. Sta. Rpt. 1927–28: 86–87. 1929.
9. **Klinge, G.** Notas sobre la industria azucarera del Hawaii. (Notes about the Hawaiian sugar industry.) Sociedad Nacional Agraria, Lima, Perú. pp. 104, 110, 111, 140. 1928.
10. **Knudson, L.** Influence of certain carbohydrates on green plants. Cornell Univ. Agric. Expt. Sta. Mem. 9: 1–75. 1916.
11. **López Domínguez, F. A.** Depreciation of cane caused by fire and by delays in shipping. Puerto Rico Insular Expt. Sta. Bul. 30: 1–52. 1922.
12. **López Domínguez, F. A.** and **del Valle, M. A.** Informe sobre la Segunda convención internacional de técnicos azucareros en Habana. Report on the Second international meeting of sugar cane technologists, Havana, pp. 1–56. 1927.
13. **Maxwell, W.** Report on fertilization. H. S. P. A. Expt. Sta. Agr. Chem. Ser. Bul. 4: 11–12. 1898.
14. **Maxwell, W.** What the crop removed from the soil. H. S. P. A. Agr. Chem. Ser. Bul. 5: 10. 1899.
15. **Mc. George W. T.** Soil and manurial studies in Hawaii. Int. Sugar Jour. 26: 75–82. 1924.
16. **O' Brien, C. H.** Burnt cane. La. Planter 68: 110–111. 1922.
17. **Owen, W. L.** The effect of burried cane trash upon soil nitrate. La. Expt. Sta. Rept. pp. 47–49. 1926.
18. **Russell, E. J.** Soil conditions and plant growth p. 266. Longmans Green Co., New York. 1927.
19. **Scott W.** Java and its sugar industry. Jour. Imp. Col. Trop. Agr. Trinidad, B. W. I., 7(3): 59–63. 1930.
20. **Verret, J. A.** Burning of sugar-cane fields. Sugar 24(5): 246–248. 1922.
21. **Waksman, S. A.** A new method for counting the number of fungi in the soil. J. Bact. 7: 339–341. 1922.
22. **Waksman, S. A.** Microbiological analysis of soil as index of soil fertility. II. Method for the study of number of microorganisms in the soil. Soil Sci. 14: 283–298. 1922.
23. **Waksman, S. A.** and **Starkey, R. L.** On the growth and respiration of sulphur oxidizing bacteria. Jour of Gen. Physiology 5(3) 285–310. 1923.
24. **Waksman, S. A.** and **Starkey, R. L.** Microbiological analysis of soil as an index of soil fertility. VII. Carbon dioxide evolution. Soil Sci. 17: 141–161. 1924.
25. **Waksman, S. A.** Principles of soil microbiology p. 727. Williams and Wilkins Co., Baltimore. 1927.
26. **Waksman ,S. A.** and **Tenney, F. G.** Composition of natural organic materials and their decomposition in the soil. III. The influence of nature of plant upon the rapidity of its decomposition. Soil Sci. 26: 155–171. 1928.

27. **Waksman, S. A.** Chemical and microbiological principles underlying the decomposition of green manures in the soil. Jour. Amer. Soc. of Agron. 21: 1–18. 1929.

28. **Waksman, S. A.** and **Tenney, F. G.** Composition of natural organic materials and their decomposition in the soil IV. The nature and rapidity of decomposition of various organic complexes in different plant materials, under aerobic conditions. Soil Sci. 28: 55–84. 1929.

29. **Waksman, S. A. and Stevens, K. R.** A system of proximate chemical analysis of plant materials. Ind. Eng. Chem. Anal. ed. 2: 167–173. 1930.

30. **Wolcott, G. N.** Influencia de la lluvia y la quemazón de la paja sobre la abundancia de *Diatraea Saccharalis.* (Influence of rain and trash burning on the abundance of *Diatraea Saccharalis.*) Estac. Expt. de la Assoc. de Productores de Azúcar, Puerto Rico. Circ. 7: 1–61. 1916.

31. **Owen Wm. L.** and **Denson, W. P.** The effect of plowing under cane trash upon the available nitrogen of the soil (From the Dept. of Bacteriology Louisiana Experiment Station). Zentralblatt fur Bakteriologie, Parasitenkunde und Infektionskrankheiten. II Abteilung 1930, Bd. 82.

A BIBLIOGRAPHY OF THE BANANA ROOT-WEEVIL

By Mortimer D. Leonard

The banana root-weevil, *Cosmopolites sordidus* Germar, is widely distributed thruout the Tropics, its distribution apparently being coincident with that of its only host plants—all species and varieties of bananas and plantains, Musa spp. Altho it is not a serious pest thruout its whole range the insect is always of sufficient importance so that its presence is viewed with alarm, for bananas and plantains are a staple food with the natives wherever they are grown and of course are a large export crop in some countries.

The literature dealing with the banana root-weevil is widely scattered in the agricultural journals and annual reports and bulletins of the departments of agriculture and agricultural experiment stations of the tropical countries of the world. To compile the present bibliography has, therefore, been no small task. Its publication is believed worth while since many of the papers included are not readily obtainable by most of the workers in tropical countries with limited library facilities.

An attempt has been made to list every reference it was possible to find in which this insect was mentioned. The relative value of each article is indicated by an annotation following the reference. A total of 215 titles is given, of which the writer has been able to personally examine all but 23; these latter are marked with an asterisk. In some cases the original publication was not seen but careful typewritten copies were received thru the courtesy of Prof. C. R. Crosby of Cornell University, Miss Mabel Colcord, Librarian of the United States Bureau of Entomology, and the Librarian of the United States Department of Agriculture. Acknowledgments are made to the above for this very necessary assistance as well as to the librarians of Cornell University and to Mr. A. J. Mutchler of the American Museum of Natural History for much help in looking up references.

Anonymous. 1916. Agricultural division. Rept. Dept. Agr. Fiji for 1915. Council Paper No. 29: 5.

Injury briefly mentioned.

1916. A new banana pest. Jour. Jamaica Agr. Soc. **20**: 25–26.

First discovered and doing considerable injury to 4-acre piece in Upper St. Andrew. Brief account; injury described; no remedies.

1916. Banana borer weevil. Jour. Jamaica Agr. Soc. **20**(11): 434–435.

Borer increasing in St. Catherine; banana clean-up order suspended because of undue hardship its full enforcement would entail.

* 1916. Proclamation concerning the black weevil borer of bananas. Jamaica Gaz. Extraordinary, 28th. April.

"Orders destruction by fire or otherwise of banana and plantain plants or parts of plants infected by the black weevil borer (*Cosmopolites sordidus*). No suckers may be planted on or removed from land found to be infested with this weevil." (Rev. Appl. Ent. 4: 320, 1916.)

* 1916. Dealing with the banana borer in Jamaica. Daily Gleaner, Kingston, Jamaica, 21st. March, pp. 13–14.

Report of special committee on banana borer of Jamaica Agr. Soc. Recommends destruction of infested suckers, planting infested land with cane or bush for a few years and planting or encouragement of bush between slightly infested or clean land. (Rev. Appl. Ent. 4: 255, 1916.)

* 1916. Black borer beetle which is attacking banana trees. Daily Gleaner, Kingston, Jamaica, 22nd. April, p. 6.

"An investigation is being made as to the areas in Jamaica on which *Cosmopolites sordidus* occurs that these districts may be declared infested and an order issued making this insect a notifiable one. It is proposed to introduce from Fiji the Histerid beetle, ***Plaesius javanus*** Er., which is predaceous on this weevil." (Rev. Appl. Ent. 4: 256, 1916.)

1916. Banana boring weevil, a new pest in bananas. Jour. Jamaica Agr. Soc. **20**: 103.

Brief reference to a former notice.

1916. The black borer weevil of banana. Jour. Jamaica Agr. Soc. **20**: 145–146.

Refers briefly to appointment of a committee of the Board of Managers of Agr. Soc. to recommend procedure

to Government. Suggested declare it pest or notifiable pest. Besides St. Andrews found in St. Catherine, but not bad.

*1917. Banana borer. Jour. Jamaica Agr. Soc. **21**(5): 169–173.

Extensive memorandum of Commissioner of Agriculture for the West Indies, Sir. Francis Watts; believes can be prevented from becoming serious by careful cultivation; trapping and selection of only healthy corms suggested. (Rev. Appl. Ent. 5: 435, 1917.)

1917. Banana borers. Banana beetle trap. Jour. Jamaica Agr. Soc. **21**: 230–231.

Brief; recommends clean cultivation and vigorous plants: young plants worst infested. Trap of ½ bulb kept fresh caught many beetles in one section.

*1918. Agricultural Experiments. Jamaica Dept. Agr. Ann. Rept. for year ended 31st. March 1918, pp. 14–18.

Recommends submerging banana suckers in water for 48 hours; trapping the adults and keeping fowls on small plantings; carbon bisulfide kills the plants. (Rev. Appl. Ent. 7: 85, 1919.)

*1918. Order relative to the black weevil borer of bananas. Jamaica Gaz. Extraordinary, 11th May.

Revokes proclamation ordering destruction of infested banana and plantain plants. (Rev. Appl. Ent. 6: 320, 1918.)

*1918. Work connected with insect and fungus pests and their control. Rept. Agr. Dept. St. Lucia 1917–1918, pp. 5–15.

Report on trip made by Dr. J. C. Hutson to investigate habits of *C. sordidus;* nature of damage and importance described in detail; recommends good cultivation and several other obvious remedies. (Rev. Appl. Ent. 6: 514, 1918.)

1919. Disposiciones vigentes sobre el servicio de sanidad vegetal. Cuba, Sec. Sanidad Vegetal, Circ. 5, p. 23.

Leaves and shoots of bananas proceeding from Jamaica prohibited entry on account of *C. sordidus.*

1919. Banana Borer. Jour. Jamaica Agr. Soc. **23**(4): 137.

Brief; soak bulbs in water for 24 hours and trap, examining the traps every 3 or 4 days.

1921. Entomología. Bol. Asoc. Agr. Ecuador **1**(3), 2 pp.

Mentioned as having been found [by H. K. Plank].

1921. Work connected with insect and fungus pests and their control. Rept. Agr. Dept. St. Lucia, 1920, p. 3.

Brief; weevil borer chiefly responsible for patches of dying bananas in peasants' holdings thruout the island; recommends destroying infested plants and clean cultivation.

1922. Os insectos damninhos XXII—Uma coleobroca da bananeira, *Cosmopolites sordidus*. [Injurious insects XXIII—A Coleopterous banana borer, C. sordidus]. Chacaras e Quintaes **26**(3) : 197–198, 5 figs.

Brief general account.

1922. Work connected with insect and fungous pests and their control. Rept. Agr. Dept., St. Vincent for 1921, p. 24.

"Caused a fair amount of damage on one plot of bananas."

1923. The banana borer (*Cosmopolites sordidus*). Agr. Circ. Dept. Agr. Fiji **3**(4) : 59–60.

Briefly mentioned as widely distributed and destructive in in Fiji.

1923. Banana borer order, 1923. Jour. Jamaica Agr. Soc. **27**(11–12), p. 1022.

Must not leave banana or plantain neglected or uncultivated. Cut infested plants into ¾ inch thick pieces and scatter over soil.

1924. The banana and its cultivation, with special reference to the British Empire. Bull. Imp. Inst. **22**(3): 319–320.

Brief general account; recommends trapping, selection of uninfested bulbs for replanting and removal of old stumps of plants after harvest.

1924. Banana borer control. Agr. Circ. Dept. Agr. Fiji **5**(1) : 75–76.

Plaesius javanus, introduced 11 years previously, now well established.

1924. Report of the division of entomology, fiscal year 1923–24. Ann. Rept. Ins. Exp. Sta. Porto Rico for 1923–24, pp. 97–98.

Trapping at the Station planting, continued from August to June, showed great reduction in numbers of weevils collected but indicates necessity of continuous trapping if borer injury is to be reduced to a minimum.

1924. Work connected with insect and fungus pests and their control. Rept. Agr. Dept. St. Vincent for 1923, p. 29.

"Found in some few instances attacking banana plants."

1925. Banana beetle borer (*Cosmopolites sordidus*). Agr. Cir. Dept. Agr. Fiji **5**(2) : 88.

Brief note on injury and extension of regulations to several additional islands.

* 1925. Proclamations under the plant diseases act. Govt. Gaz. [New South Wales] No. 97.

Listed as a pest for purposes of the Act. (Rev. Appl. Ent. 13: 639, 1925.)

1925. Banana root-stock borer. Farming in S. Africa **1**(6) : 209.

Records first discovery of *C. sordidus* in South Africa in 1924 in Natal and quotes from Mc Carthy's account in Agr. Gaz. N. S. Wales (1920).

1927. Libya: decree of 13th. September 1926 on importation of plants. Internat. Rev. [Sci. & Pract.] Agr. N. S. **18**(3) : T187–T188.

Brief note; banana plants from every source prohibited importation on account of *C. sordidus*.

1927. Cuarentena exterior Num. 7. Bol. Mens. Defensa Agr. Sec. Agr. y Fomento, México **1**(7) : 536–537.

Note stating that importation of banana plants or parts from foreign countries is prohibited on account of *C. sordidus*.

* 1927. New South Wales: Plant Diseases Act. 1924. Regulations Nos. 27–31. Govt. Gaz. No. 168, reprint, 2 pp.

Banana plants restricted in movement and infested plants to be treated in several ways. (Rev. Appl. Ent. 16: 124, 1928.)

* 1928. New South Wales: Proclamation under the plant diseases act, 1924. Govt. Gaz. No. 128, reprint, 1 p.

Prohibits introduction of banana, plantain or manilla hemp plants or plant parts, except under permit on account of *C. sordidus*. (Rev. Appl. Ent. 17: 103 1929.)

1929. Report of the division of entomology, Ann. Rept. Ins. Exp. Sta. Dept. Agr. & Labor Porto Rico for 1927-1928: 95.

Brief note.

1930. Division of Entomology. Rept. Comm. Agr. and Labor Porto Rico for fiscal year ended June 30, 1929, p. 700.

Note stating that studies have been made; damage is serious.

Ballou, H. A. 1912. Insect pests of the Lesser Antilles. Imper. Dept. Agr. West Indies, Pamphlet Ser. 71, p. 112.

Brief mention.

1916. The banana weevil. Agr. News [Barbados] **15** (364): 123.

Brief account of general distribution, habits and spread; recommends destroying all infested stools and replanting only uninfested ones.

1922. Insect pests of plantains and bananas. West Ind. Bull. 19(2): 267.

Listed as generally distributed and doing severe damage in St. Lucia, B. W. I.

1928. Control of insect pests. Rept. St. Lucia Agr. Dept. for 1927, p. 10.

Mentioned as causing bananas to be treated by the Banana Inspectors.

1929. Diseases and pests within the colony. Rept. St. Lucia Agr. Dept. for 1928, p. 14.

Mentioned as a pest in order to comply with requirements of the Plants Protection Ordinance.

1931. Banana borer. Jour. Jamaica Jour. Agr. Soc. **35**(2): 63.

Still doing considerable damage in some centers while in others reasonably well controlled; urges covering crown of

growing plant with earth and also butts after cutting back to the crown; also systematic trapping and cleaning up débris and chopping up of stumps within one month after harvesting bananas.

Barrett, O. W. 1928. The Tropical Crops, pp. 182–183.

Brief statement of nature and extent of damage.

Benson, A. H. 1920. Remedies suggested [for the banana weevil.] Queensl. Agr. Jour. **13**(4) : 168.

Brief description of precautionary measures, destruction of beetle in infested plantations, and how to destroy infested plants.

Brugiroux, A. 1928. French Settlements in Oceania: some insects damaging crops. Internat. Rev. [Sci. & Pract] Agric. **19**(4) : 400.

C. sordidus listed as a pest in Tahiti.

Carment, A. G. 1922. Report on mycological work done by Dr. A. G. Carment, medical officer of health and bacteriology. Dept. Agr. Fiji. Ann. Rept. for the year 1921. Council Paper No. 56 : 8.

Brief note.

Charmoy, D. d' E. (See d' Emmerez de Charmoy.)

Cedaña, S. M. 1922. The banana weevil. Philippine Agr. **10** : 367–376, 2 pl.

Good general account for the Philippines; experimental data on injury, life history and control; a serious pest also of abaca (*Musa textilis* Nee.); bibliography of 14 titles.

Chevrolat, A. 1880. Diagnoses de curculionides de la Martinique. Le Naturaliste 1 : 198.

Original description of *Sphenophorus pygidialis* listed doubtfully as a synonym of *C. sordidus* by Fletiaux and Sallé who state that the single type specimen could not be found in the Chevrolat collection.

1885. Calandrides. Ann. Soc. Ent. France, Ser. 6, **5** : 289–290.

Cosmopolites described as new genus. *Calandra sordida* Germar given as type and said to occur in Brazil, Java, Ceylon, Malacca, Saigon, China, Reunión, etc.

Crosby, C. R. and **Matheson, R.** 1914. Catalogue of [injurious] insects. In Cyclopedia of Horticulture by L. H. Bailey, **2**: 1049.

Listed as injurious.

Dammerman, K. W. 1929. The Agricultural zoology of the Malay Archipelago. The animals injurious and beneficial to agriculture, horticulture, and forestry in the Malay Peninsula, the Dutch East Indies and the Philippines, p. 98.

Brief general account; no control; *Placsius javanus* and *Crysopilus ferruginosus* mentioned as predators. This English edition is a revised and enlarged one based on the work in Dutch of about the same title published in 1919 in Amsterdam

de Azevedo Marques, L. A. 1922. A praga de bananeira no Río de Janeiro. (Biología de *Cosmopolites sordidus* Germ.). Bol. Soc. Ent. Brazil, 1922(1,2,3): 24–32, 2 figs.

Good, rather brief account of life history and control; first recorded in Brazil in 1918. Egg period determined as 8 days, larval 22, and pupal as 10, and various control measures discussed, including use of carbon bisulfide.

1923. A praga de bananeira no Rio de Janeiro. (Biologia do *Cosmopolites sordidus* Germar). Bol. Minist. Agr. Ind. e Comm., **11**(5): 109–117, 2 pls. (Dec. 1922).

Stages, life-cycle (40 days) and habits described; various measures recommended, including carbon bisulfide.

d' Emmerez de Charmoy, D. 1928. Entomological division. Ann. Rept. Dept. Agr. Mauritius for 1927, p. 13 (Port Louis).

"Bananas were reported as in previous years to be severely attacked with the stem beetle, *Cosmopolites sordidus*. Instructions for coping with the pest were issued to those concerned.

d' Emmerez de Charmoy, D. and **Gebert, S.** 1921. Insect pests of various minor crops and fruit trees in Mauritius. Bull. Ent. Res. **12**(2): 190.

"Banana.—The black banana weevil, *C. sordidus* Germ. is the only pest. The larvae live in the root-stock and occur

sometimes in such great numbers as to cause the death of the plant. The varieties known as 'Gingeli' and 'Banana Carrée' are particularly affected.''

de Seabra, A. F. 1920. Études sus les maladies et les parasites du cacaoyer et d' autres plantes cultivées á S. Thomé. 22. Le *Cosmopolites sordidus* Germ., á S. Thomé. Lisbon, Companhia Agr. Ultramarina, pp. 3–7.

General account of in the Island of San Thomé; known as a pest since 1907.

1922. Études sur les maladies et les parasites du Cacaoyer et d' autres plantes cultivées a S. Thomé. No. 22. Le *Cosmopolites sordidus* Germ. a S. Thomé. Mém. publ. par Soc. Portugaise Sci. Nat., Sér. Zool. No. 2, fasc. **2**: 101–104, 3 figs.

Brief account of nature of damage, detailed description (with figures) of the adult, with a note on several color variations; states it was recorded by Gravier in S. Thomé in 1906.

* 1922. Insects de S. Thomé provenant de la mission d' étude du Professeur Sousa da Camara en 1920.—Separate from Anais do Instituto de Agronomia, 21 pp., Coimbra, Portugal.

Recorded as attacking banana. (Rev. Appl. Ent. 11: 308, 1923.)

Dejean, P. F. M. A. 1837. Catalogue des coleoptéres, 3rd. ed. p. 329.

Calandra striata Petit listed from Brazil; is also listed in 2nd Ed. p. 304 but I have not seen a copy of this edition.

Despeissis, A. 1924. Dept. Agr. Fiji Ann. Rept. for the year 1923. Council Paper 53: 3–4.

P. javanus has become established over an extensive area on the Rewa River and its tributaries; sanitation recommended.

Drieberg, C. 1916. Ceylon Agricultural Society; progress report 49. Trop. Agr. (Peradeniya) **46**(3): 191.

Note recording a plantain shoot received from Uda Alu deniya as infested.

* **Dupont, P. R.** 1915. Insect notes of curator, Botanic Station, Sychelles, 18th. March.

A consignment of Gros Michel banana suckers imported from Fiji were infested. (Rev. Appl. Ent. 3: 410, 1915.)

* 1918. Insect Notes. Curator's Report on Botanic Station, Seychelles, for 1917. (MS from Colonial Office, received by R. A. E. 24th. June, 1918.)

Reported that bananas were badly infested. (Rev. Appl. Ent. 6: 377, 1918.)

Edwards, W. H. 1925. Le charançon du bananier, *Cosmopolitis sordidus* Germ. Rev. Agr. de l' île Maurice, No. 22: 513–514.

Most important banana pest in Mauritius; length of stages given; best control is— burn all suspected plants, plant only healthy corms and use bait traps of pieces of corms.

Fahraeus, O. J. in C. J. Schoenherr's (1845) Genera et species curculionidum, cum synonymia hujus familiae, **8**(2): 251–252.

Original description of *Sphenophorus striatus* from Brazil.

Fawcett, W. 1913. The banana, its cultivation, distribution and commercial uses. (London), pp. 99–101.

Brief general account.

Fernández García, R. 1930. [Informe del] Estación Experimental Insular. Sección de Entomología. Inf. An. Com. Agr. y Trab. año fiscal 1929–1930: 181.

Brief note on beneficial results obtained by "cleaning" infected suckers with a knife; reduction of weevils by trapping and suggestion that attempt be made to introduce the predators, *Placsius javanus* Er. and *Chrysopilus ferruginosus* Weid.

Fletcher, T. B. 1914. Some South Indian Insects, pp. 342-343. 1 fig.

Brief account; recorded from Malabar, Coimbatore, Godavari and Ganjam; usually a minor pest of plantain but occasionally doing considerable damage; destroy old stumps and use only uninfested suckers.

1917. Rept. Proc. Second Ent. Meeting held at Pusa, pp. 238–239.

Brief notes on distribution (thruout S. India and in W.

India as far north as Poona); destroy old infested stumps and select only non-infested suckers.

1920. An annotated list of Indian crop pests. Proc. Third Ent. Meet., Pusa **1**: 208.

Briefly recorded as a pest in certain parts of India and Ceylon.

* **Fletiaux, E.** 1903. Les Insects. Agr. Prat. Pays Chauds 2(10): 495–502; (12): 745–760.

Fletiaux, E. and **Sallé, A.** 1889. Coleoptéres de la Guadeloupe. Ann. Soc. Ent. France, Sér. 6 Vol 9: 455.

Listed as having been found in several localities in the island and as being common in rotten bananas. Four synonyms given—*striatus* Fahrs, *crenatus* Sturm., *javanus* Westerman in litt.) and doubtfully, *pygidialis* Chev.

Freeman, W. G. 1924. Plant Pathology. Rept. Dept. Agr. Trinidad and Tobago, for year ended Dec. 21st. 1924, p. 24.

"Continued to be a pest in all districts and during the year was recorded for the first time from Tobago."

Froggatt, W. W. 1919. The black banana stem weevil (*Cosmopolites sordidus* Germ.) Agr. Gaz. New South Wales **30**(11): 815–818, 6 figs.

Apparently first or at least one of earliest records of pest in New South Wales. Brief account of distribution, life-history and stages; excellent figures.

Froggatt, J. L. 1921. Banana beetle borer investigations (First Progress Report). Queensl. Agr. Jour. **16**(3): 200–208, 4 pls.

Report on the first half year's investigations on habits and life-history of the insect; control brief.

1922. The banana beetle borer, *Comopolites sordidus* Chev. (Curculionidae). (Second Progress Report.) Queensl. Agr. Jour. **17**(1): 39–45, 2 figs.

Brief description of life-history, habits and stages; detailed life-history data.

1922. Banana beetle borer. Queensl. Agr. Jour. **17**(5): 240–242, 2 figs.

A brief resumé of information obtained to date on injury, life-history and control.

1922. The banana beetle borer. Queensl. Agr. Jour. **18** (1) : 48–49.

Information on nature of injury, life-history and control, mostly quoted from previous reports.

1922. The banana beetle borer III. Queensl. Agr. Jour. **18**(4) : 279–288, 3 pls.

Life-history, injury and experiments of tests of chemicals to kill beetles with baits of corms; control measures outlined.

1923. The banana beetle borer. IV. Queensl. Agr. Jour. **19**(2) : 68–75, 3 pls., 6 tables.

Detailed life-history and control experiments: 96 hours in water 90 per cent beetles still alive and remained so for 10 days. P. D. B. (Paradiclorbenzene) kills in confined space.

1923. The banana beetle borer. V. Queensl. Agr. Jour. **19**(6) : 523, 5 pls.

Good account—life history and control experiments. Paris green best on sliced corms; after feeding 18–48 hours 99.4 per cent beetles died; sodium arsenite powder killed 92.5 per cent in 18–54 hours.

1924. The banana weevil borer. Queensl. Agr. Jour. **21**(4) : 275–276.

Brief report of three years' investigations to-date on life-history and habits.

1924. Banana weevil (*Cosmopolites sordidus* Chev.). Queensl. Agr. Jour. **21**(5) : 369–378, 2 pls.

Sixth progress report; beetles went 121 days without food; detailed account of experiments to date.

1924. Banana weevil borer. Queensl. Agr. Jour. **22**(3) : 154–156.

Brief summary of previous observations and experiments with detailed control recommendations based thereon; stated that liberation of *Plaesius javanus*, the predatory Histerid beetle from Java, is being continued on a small area near Brisbane and several adults found 2–3 months after liberation.

1925. The banana weevil borer (*Cosmopolites sordidus* Chev.). Queensl. Agr. Jour. **24**(6) : 558–593, pls. 140–148.

One of the best full accounts of this insect.

1926. The Banana Weevil Borer. Queensl. Dept. Agr. and Stock Div. Ent. and Plant Path. Bul. 4(N.S.) 40 pp., 9 pls.

Excellent full account for Queensland.

1928. Notes on banana insect pests. Queensl. Dept. Agr. and Stock, pp. 1–2.

Brief statement of nature of damage, varieties infested and general world distribution.

1928. Baiting for banana weevil control. Queensl. Dept. Agr. and Stock, 2 pp.

Materials and method described.

1928. Baiting for banana weevil borer control. Queensl. Agr. Jour. **29**(4) : 282–283.

Detailed description of how to make and use bait traps for catching adults.

1928. The banana weevil borer in Java with notes on other crop pests. Queensl. Agr. Jour. **30**: 530–541, 1 pl.

Same as Div. Ent. and Plant Path. publication which follows.

1928. The banana weevil borer in Java with notes on other crop pests. Div. Ent. and Plant Path., Dept. Agr. and Stock, Queensland, 12 pp., 1 pl.

Economic status in Java with notes and descriptions of the predators—*Chrysopila ferruginosa* Weid. and *Plaesius javanus* Er.—and their introduction into Queensland.

Germar, E. F. 1824. Coleopterorum novae aut minus cognitae descriptionibus illustratae, 1, (Coleoptera) p. 299, 2 pl. (Halae).

Original description as *Calandra sordida;* habitat given as the East Indies ("India orientali").

Ghesquiére, J. 1924. La maladie des bananiers dans le Bas-Congo. Bul. Agr. Congo Belge **15**(1) : 171–172.

C. sordidus continuing to spread; first found near Zobe about 1913–14 and now found from the extreme west of Mayumbe to near Kisantu.

1925. La maladie du bananier au Congo Belge. (Notes complémentaires.) Bul. Agr. Congo Belge **16**(3–4): 556–560.

Brief general account.

1927. La maladie du bananier au Congo Belge. Rev. Zool. Bot. Afr. Suppl. 15 (Bull. Cercle Zool. Congolais **4**(1) : [59]–[68], 1 fig.

Good account of insect and control in Belgian Congo. 17 references.

González Ríos, P. 1922. El gorgojo del banano. Rev. Agr. Puerto Rico **9**(6) : 39–42, 3 figs.

Brief general account for farmers in the Island, describing recent discovery and giving life-history, nature of injury and suggesting urgent need for prevention of spread.

1930. Cultivo del banano en Puerto Rico. Est. Exp. Ins. P. R. Bol. 36: 49–51, 2 figs.

Brief general account for Porto Rico.

Goodman, W. S. 1929. Report of the Plant Breeder. Ann. Rept. Jamaica Dept. Agr. for Year Ended 31st. Dec. 1928, p. 13.

Brief; trapping has given good results.

Gowdey, C. C. 1920. Report of the government entomologist for 1918–1919. Uganda Dept. Agr. Ann. Rept. for year ended 31st. March 1919, p. 39.

Occurs not only on mainland but also on Bukassa Island, Sesse Group, which has been uninhabited for years; always worse on old uncultivated plots; recommends good cultivation and sanitation and rearing of the predaceous Histerid beetles.

1921. Annual report of the government entomologist Ann. Rept. Jamaica Dept. Agr., for 1920: 25–27.

Brief note—favored by: poor soil, cultivation, land on bananas for long period, failure to destroy old bulbs and

excessive mulching; recommends cultivation, rotation and systematic trapping.

1922. [Annual report of the] Government entomologist. Ann. Rept. Jamaica Dept. Agr. 1921: 40.

Briefly notes several attacks which were investigated; due to planting infested suckers but in one planting control measures greatly lessened trouble.

1922. The banana borer, (*Cosmopolites sordidus* Germar). Jamaica Dept. Agr. Ent. Circ. 8, 8 pp., 2 pls.

General account; original life-history data with control; bibliography of six titles; the Histerid beetle predator, *Plaesius javanus*, not very successful.

1923. The principal agricultural pests of Jamaica. Dept. Agr. Jamaica Ent. Bul. 2: 24–27, 2 pls.

Full account with control measures.

1923. Report of government entomologist, Ann. Rept. Jamaica Dept. Agr. 1922: 23.

Brief account; increasing in certain districts, but trap method satisfactory wherever systematically carried out.

1924. Report of the government entomologist. Ann. Report. Dept. Agr. Jamaica, 1923: 20.

Brief; very prevalent—a dry year; paris green and sodium arsenite on corms gave 80–90 per cent kill of weevils in 24 hours; suckers in water for 24 hours killed a certain number of all stages.

1925. Report of the government entomologist. Ann. Rept. Jamaica Dept. Sci. and Agr. for year ended 31st. Dec. 1924, pp. 17–18.

Three new localities infested, but situation in general greatly improved due to trapping and destruction of old bulbs.

1926. Report of the government entomologist. Ann. Rept. Jamaica Dept. Agr. for year ended 31st. Dec. 1925, p. 10, 11.

Control improving and no new localities infested; mention of experiments being conducted with paradichlorobenzene.

1927. Report of the government entomologist. Ann. Report. Jamaica Dept. Agr. for year ended 31st. Dec. 1926, p. 16.

Reported from two new localities; experiments with paradichlorobenzene reported to appear somewhat promising.

1928. Report of the government entomologist. Ann. Rept. Jamaica Dept. Agr. for year ended 31st. Dec. 1927, p. 20.

One new locality infested; experiments with a crude paradichlorobenzene continued and on one property 75 to 85 per cent effectiveness was obtained.

Gravier, Ch. 1907. Sur un coléoptore (*Spenophorous striatus* Fahr.) qui attaque les bananiers a San-Thomé (Golfe de Guinée). Bul. Mus. Nat. d' Hist. Nat., Paris, 13: 30–32.

Brief account of the banana root weevil (as *Sphenophorus striatus* Fahr.) in San Thomé where he states it is considerable of a pest; nature of injury briefly described and the account by Acacio Magro abstracted, who recommends chiefly immersion [of infested plants or bulbs ?] in „Bordeaux mixture.

Gyllenhal, L. 1838 in Schoenherr's Genera et species curculionidum **4**(2) : 925–926.

Technical description; habitat given as Java; from collection ("A. Dom.") Schuppel and Westermann.

Hadden, F. C. 1928. Some injurious insects of Formosa. Jour. Pan–Pacif. Res. Inst. **3**(1) : 14.

"Bananas are attacked by *C. sordidus*, a recently accidentally introduced root and stalk beetle borer".

Hancock, G. L. R. 1926. Annual report of the assistant entomologist. Ann. Rept. Dept. Agr. Uganda, 1925, p. 28.

Listed as injurious.

Hargreaves, H. 1922. Annual report of the government entomologist, 1921. Uganda Dept. Agr. Ann. Rept., 1921 : 62.

"No serious outbreak of this pest has been noticed. Larvae and pupae found on dying stems from which fruit had been cut."

1924. Ann. Rept. of the government entomologist. Uganda Ann. Rept. Dept. Agr. 1923, p. 19.

"Reported to be present in large numbers on two areas. Cutting out and destruction of infested stocks and the collection of adult weevils by means of trap stocks was recommended."

1925. Annual report of the government entomologist. Uganda Ann. Rept. Dept. Agr. 1924, p. 25.

Forty per cent of plantain trees in a garden infested.

1926. Report on the entomological section. Ann. Rept. Lands & Forests Dept. Sierra Leone for 1925, p. 16.

Listed as attacking bananas.

1928. Annual report of the government entomologist. Rept. Dept. Agr. Uganda, 1927, 11 pp. typescript.

Brief statement that a widespread outbreak of *C. sordidus* occurred on plantain and banana but the natives did little or nothing to control the pest.

(?) Harris, W. 1916. Report of the superintendent of public gardens. Suppl. to Jamaica Gaz. **39**(7) : 118.

"Found to be attacking a small area of banana on the hillside west of the gardens but none of the plants in the gardens were attacked. It was decided however to destroy all plants on the garden lands."

Hopkins, G. H. E. 1927. Pests of economic plants in Samoa and other island groups. Bul. Ent. Res. **18**(1) : 28.

"Swezey found this species attacking bananas and suggested that it was then recently established. It is still by no means common and does little damage."

Howard, L. O. 1930. A history of applied entomology (Somewhat annecdotal). Smithsonian Misc. Coll. Vol. 84 (whole volume) Publ. 3065, pp. 413, 513, 523.

Brief mention of introduction of the Histerid beetle, *Placsius javanus* into Fiji and later into Queensland, in both as predators of the banana root-weevil.

Hutson, J. C. 1921. Report of the division of entomology, April–June, 1921. Trop. Agr. [Ceylon] **57**(3) : 194.

"Found to be prevalent [in the plantain districts] especially in plantations which are allowed to run more than two years without replanting. The work is being carried on."

1922. Report of the entomologist. Ceylon Dept. Agr. Rept., 1921: C. 23–26.

Brief: stated as prevalent in two areas injuring plantains; usually worse where no planting has been done for several years.

Jardine, N. K. 1924. Plantain root beetle borer. Dept. Agr. Ceylon, Leaflet 29, 1 p. 1 pl.

Brief account of life-history and control.

(?)1924. Plantain root beetle borer (*Cosmopolites sordidus* Germar). Yearbk. Dept. Agr. Ceylon, 1924, pp. 55–58.

Brief general account, mostly compiled from literature; trapping recommended.

* **Jepson, F. P.** 1911. Report on economic entomology. Fiji Dept. Agr. Council Paper 25, 89 pp., 7 pls.

1914. A mission to Java in quest of natural enemies for a coleopterous pest of bananas (*Cosmopolites sordidus* Chev.). Dept. Agr. Fiji Bul. 7, 18 pp., 3 pls.

General distribution; life-history in Fiji, habits and stages described of *Placsius javanus* Er., *Chrysopilus ferruginosus* Wied. and data on amount of *C. sordidus* larvae eaten by them; transportation of beetles to Fiji; five references cited.

1915. Division of entomology. Dept. Agr. Fiji. Ann. Rept. for 1914: 20.

Less abundant than in previous years, especially in districts in which the predaceous Histerid beetles from Java (*Placsius javanus*) had been established; data on status of *P. javanus* since introduction.

1916. Report on a visit to the Rewa River plantations. Dept. Agr. Fiji Pamphlet 25, p. 1.

Less prevalent than three years previously due to exceptionally wet season; conditions conducing to its spread are: poor drainage; neglect in planting only healthy suckers; failure to rotate often enuf; planting too close and leaving infested stems and stumps on ground.

1917. Division of entomology. Dept. Agr. Fiji Ann. Rept. for year 1916. Council Paper 107: 16.

Continued to be injurious to some plantings but apparently less so than formerly.

1919. Division of entomology. Fiji Dept. Agr. Ann. Rept. for the year 1918. Council Paper No. 32:15.

Another importation of the predaceous beetle, *Plaesius javanus* from Java was received.

1924. Report of the acting entomologist. Ceylon Administ. Rept. Dept. Agr. 1923, p. D–20.

"The platain root borer (*Cosmopolites sordidus*) continues to cause considerable damage to plantains in the Rambukana and Matale Districts."

Jepson, F. P. and **Knowles, C. H.** 1920. Division of Entomology. Ann. Rept. Fiji Dept. Agr. for the year 1919. Council Paper No. 65. pp. 7–14.

Outline of proposed investigations.

Kermack, James. 1930. Fruit production for export.—Part II,—cultivation of the banana in Fiji. Agr. Jour. Dept. Agr. Fiji **3**(1):36–37.

Recommends trapping weevils; *Plaesius javanus* is proving a successful predator.

Knowles, C. H. 1907. Agriculture (Report on, for the year 1906). Legislative Council Fiji. Council Paper No. 13, p. 7.

Appears to have been present for some time and becoming more common; destroy infested plants.

1909. Agriculture (Report on, for the year 1908) Legislative Council Fiji, Council paper 27, p. 20.

Injurious during the year; carbon bisulfide recommended.

1911. Agriculture (Report on, for the year 1910) Fiji. Council Paper No. 23, p. 5.

Mentioned.

1918. Division of entomology. Fiji Dept. Agr. Ann. Rept. for 1917. Council Paper No. 60:8–9.

Prevalence and amount of damage; injury mostly on outer half of bulb; trapping and cultivation recommended; *P. javanus* introduced in 1913, not seen during 1917.

1919. Inspection of plantations. Fiji Dept. Agr. Ann. Rept. for the year 1918, Council Paper 32, p. 11.

Reported as much more plentiful during the year than formerly.

1919. Division of Entomology. Fiji Dept. Agr. Ann. Rept. for 1918, Suva, Council Paper 32:13–14.

Serious damage during the year; generally distributed throughout the Colony; experiments shows that traps are effective but must be destroyed every 21 days; old infested plantations should be ploughed out; *Plaesius javanus* in two consignments reintroduced during year.

1920. Agricultural work of the department. Fiji Dept. Agr. Ann. Rept. for the year 1919. Council Paper No. 65, pp. 5, 13.

Note on trapping beetles; beetle shows preference for West Indian plantains; is of the opinion that poor condition of plants in certain areas due to weevil.

1921. Entomological. Fiji Dept. Agr. Ann. Rept. for the year 1920. Council Paper No. 38, p. 8.

Continued injurious; *Plaesius javanus* slow in increasing.

* **Knowles, C. H.** and **Jepson, F. P.** 1912. The banana in Fiji. Dept. Agr. Fiji Bul. 4, 17 pp., 3 pls.

Lawson, D. O. K. 1917. The striped cane weevil. Jour. Jamaica Agr. Soc. **21**(6):219–220.

C. sordidus mentioned in connection with brief discussion of control of striped cane weevil.

Leng, C. W. and **Mutchler, A. J.** 1914. A preliminary list of the Coleoptera of the West Indies as recorded to January 1, 1914. Bul. Am. Mus. Nat. Hist. 33, Art. 30:478.

Listed from Guadalupe.

1917. Supplement to preliminary list of the Coleoptera of the West Indies. Bul. Am. Mus. Nat. Hist. 37, Art. 5:218.

Listed from Dominica.

Leonard, M. D. 1931. Entomology in Puerto Rico during the past decade. Jour. Econ. Ent. **24**(1):146.

Brief note on status in the island.

López Domínguez, F. A. 1927. Informe anual del director de la estación experimental Insular de Puerto Rico, año fiscal 1925–26, p. 48.

Brief; has continued to spread as far as Utuado; Austra-

lian method of dusting the corms with Paris green and flour will be tried next year.

Mackie, D. B. 1917. A summary of the work of the pest control section for the year 1916. Philippine Agr. Rev. **10**(2) : 137–138.

Brief reference to death of a large number of abaca plants in Paete, Laguna.

1918. Some pests we do not want, why we do not want them, and how they may arrive. II. The banana root borer. Calif. State Comm. Hort. Bul. **7**(8) : 498–502 3 figs.

Refers to Federal quarantine 31 prohibiting entry of banana plants for propagation; general distribution, habits and injury described; especially in Philippines, grubbing out and burning infested plants recommended.

* **Magro, Acacio.** 1906. O musaphago ou bicho que ataca a bananeira pão; meies practicos de o destruir, San Thomé, 1906.

Mayné, R. 1916. Rapport sur une maladie des bananiers au Mayumbe (Bas-Congo). [Report on a banana plant disease at Mayumbe (Lower Congo)]. Bull. Agr. Congo Belge **7**(3–4) : 236–239.

Brief general account of the insect in Mayumbe.

McCarthy, T. 1920. Banana root borer, (*Cosmopolites sordidus* Germar). Agr. Gaz. New South Wales **31**(12) : 865–872, 2 pls., 1 fig.

Good general account but no experimental data included

McCreadie, J. 1922. Nasinu Experimental Station. Overseer's Report. Ann. Rept. Fiji Dept. Agr. for the year 1921. Council Paper No. 56, p. 5.

Plants poor owing to attacks of beetle; large numbers of beetles caught by trapping.

Misra, C. S. 1920. Index to Indian fruit pests. Proc. Third. Ent. Meet. at Pusa **2** : 593.

Listed as injurious to plantain.

Moreira, Carlos. 1922. Broca da bananeira. Chacaras e Quintaes **25**(3) : 233–234.

Brief note regarding injury.

Moznette, G. F. 1920. Banana root borer. Jour. Agr. Res. **19**: 39–46, fig. 1, pls. 8–11.

Good account of the insect in Florida based on experimental data; detailed description of the stages of the insect; destruction of infested plants and use of bait traps recommended.

Muir, F. 1907. Notes on the sugar-cane hoppers and borers in the Malay States and Java. Rept. work Expt. Sta. Hawaiian Sugar Planters' Assn. Div. Ent. Circ. 2, pp. 8–9.

Mentioned as being fairly common in banana stems; stated that a large black Histerid beetle and its larva as well as the larvae of certain Hydrophiiids feed on larvae of *C. sordidus*.

1908. Entomological Work in Borneo. Rept. work Exp. Sta. Hawaiian Sugar Planters' Assn. Div. Ent. Circ 4, p. 5.

Mentioned as being found (in company with *Sphenophorus ferrugineus*) in banana and palm trees, attended by Hydrophilid and Histerid beetle predators as in Java.

Muir, F. and **Swezey, O. H.** 1916. The cane-borer beetle in Hawaii and its control by natural enemies. Rept. Haw. Sugar Planters' Assn. Expt. Sta. Ent. Bul. 13: 15, 16 (and pp. 58, 61, 67).

(P. 15) Note on *Placsius javanus* being found as predaceous on *C. sordidus* and sent from Java to Honolulu; (p. 16) note stating that *Chrysopila* sp. larvae were numerous in sago palms and banana trees feeding upon beetle and dipterous larvae; Jepson's observations on both predators referred to. Pages 58, 61 and 67 are contained in reprints of Ent. Circulars 2 and 4 (See Muir 1907 and 1908).

Murray, P. W. 1918. Agricultural experiments. Suppl. to Jamaica Gaz. **41**(9) : 182–184.

General account of distribution, habits, injury and control in Jamaica; burning difficult; carbon bisulfide not practical on plants buried under soil; soaking suckers 48 hours in water effective; good cultivation and clean management all necessary for effective control.

Newell, W. 1919. Report of the plant commissioner for the biennium ending April 30th., 1918, and Supplemental Reports. Quart. Bul. Fla. St. Plant Bd. **3**(2) : 47–49.

Found in one nursery and all banana plants there and in adjacent properties were destroyed.

1921. Report of the plant commissioner for the biennium ending April 30th., 1920, and supplementary reports. Quart. Bul. Fla. State Plant Bd. **5**(2) : 94–95.

States that it is also known to attack sugar cane [this is undoubtedly in error]; refers to eradication campaign in Manatee Co. in 1918 and of elimination of an infestations in Polk Co. in 1918; in Dade Co. in 1919 and 1920 several infestations were cleaned up and the State is apparently clean.

Newman, L. J. 1924. Report of economic entomologist. West Austr. Dept. Agr. Ann. Rept. for the year ended June 30, 1924, p. 22.

"Two outbreaks of this weevil were recorded during the year in the North West. In both instances the North-West Department was advised to destroy by fire the whole of the plants. This was done and the outbreaks suppressed. Carnavon District still infested. The Southwest apparently not yet infested."

Ogilvie, L. 1924. Notes on plant diseases and pests. Agr. Bul. Bermuda Dept. Agr. **3**(2) : 6.

Brief note: prevalent wherever bananas are grown in unsuitable soil or are not properly cultivated; attention should be paid to proper cultivation, rotation of crops where possible and systematic trapping with baits of banana stems or bulbs, and traps examined every three days.

1924. Preliminary report of the plant-pathologist for the period September 27th. to December 31st., 1923. Bermuda Repts. Bd. and Dept. Agr. 1923, p. 29.

Briefly stated as only of serious importance where bananas are grown in unsuitable soil or situation or are otherwise weakened.

1928. The Insects of Bermuda. Dept. Agr. Bermuda, [unnumbered publication], p. 16.

"Of serious importance in Bermuda only where bananas are grown in unsuitable soil or situation or where the plants are otherwise weakened."

Pierce, W. D. 1917. A manual of dangerous insects likely to be introduced in the United States through importations, pp. 34, 207. U. S. Dept. Agr. Office of Sec'y.

Brief; life history; also lists sugar cane as a host [undoubtedly in error]; distribution is: Fiji, British West Guinea [in Eastern Hemisphere south Pacific Ocean to Indian Archipelago] Jamaica, India, Brazil.

Pinto, M. P. D. 1928. The two weevil pests of plantains. (Musa sapientum L.) *Cosmopolites sordidus* Germ. and *Odoiporus longicollis* Oliv. Trop. Agr. **70**(4) : 216–224, figs. 1–5.

Life-history and control for Ceylon; bibliography of 7 titles.

Pynaert, L. 1921. Les bananiers. Bul. Agr. Congo Belge, **12**(2) : 249–251.

Brief general account with suggested control.

Ramakrishna Ayyar, T. V. 1922. The weevil fauna of South India with special reference to species of economic importance. Agr. Res. Inst., Pusa, Calcutta, Bul. 125, p. 19, fig. 1, pl. 20.

"Brief mention of *C. sordidus* as occasionally injurious to the stems of growing banana plants, but noted so far only in Malabar and the Northern Sircars."

1923. Some insects noted as pests of fruit trees in South India. Agr. Jour. India **18**(1) : 50–59.

"Tho found in a few places in South India, has not yet assumed the status of a serious pest."

Reh, L. 1913. Die tierischen Feinde, in P. Sorauer's Handbuch der Pflanzenkrankheiten **3** : 566.

Mention.

Ritchie, A. H. 1916. Report of entomologist for year 1915–1916. Ann. Rept. Jamaica Dept. Agr. for year ended 31st. March 1916, p. 33.

"The presence of the black weevil of banana (*C. sordidus* Germ.) in the Island was brought for the first time to the attention of banana planters by the Entomologist in late November, 1915. This insect has already formed the subject of independent and extended report."

*1916. The black beetle attacking banana cultivations. Daily Gleaner, Kingston, Jamaica, 22nd. January, p. 18, 2 figs.

Brief general account of distribution and injury; cooperation in control urged. (Rev. Appl. Ent. 4: 175, 1916.)

1917. Annual report of the government entomologist for year 1916–1917. Suppl. to Jamaica Gaz. **40**(4) : 97.

Very briefly summarizes a report submitted in December—mention of the beneficial grub of *Pyrophorus* sp. (Elateridae); adults lived in banana trash in the laboratory for 159 days.

1919. Annual report of the government entomologist for 1918–1919. Jamaica Dept. Agr. Ann. Rept. for year ended 31st. Mar. 1919, p. 28.

Note stating that two consignments of *Plaesius javanus* from Java were received but most of them died on the way.

Rivera, E. M. 1927. Informe sobre el trabajo de estudios del gorgojo del ñame del banano. Rev. Agr. Puerto Rico **19**(2) : 59–62, 1 fig., 1 map.

Description of a survey to determine the presence and abundance of the insect in three districts in the Island.

Rodríguez Barrera, J. 1928. El banano, pp. 82–83 [Manual del agricultor en Fernando Póo, III, Madrid].

Brief account.

Sasscer, E. R. 1915. Important insect pests collected on imported nursery stock in 1914. Jour. Econ. Ent. **8**(2) : 269.

Records a single specimen in a plant from Brazil, which in several months finally caused the plant to die down.

1916. Important foreign insect pests collected on imported nursery stock in 1915. Jour. Econ. Ent. **9**: 218.

"Plants from the Philippines found to be severely infested."

Schultze, W. 1915. A catalog of Philippine coleoptera. Manila. Philippine Jour. Sci. 11, Sec. D., p. 148.

Listed from Luzon, Mindanao and Palawan.

Seín, Jr., F. 1923. El gorgojo del ñame del guineo. P. R., Ins. Exp. Sta. Circ. 82, 7 pp., 2 figs.

Brief general account.

1929. El gorgojo del ñame del guineo en Puerto Rico. El Mundo (San Juan, P. R.), Oct. 6, p. 15., 4 figs.

Popular account of life history, injuries, and control.

Simmonds, H. W. 1920. Report on mission to Tahiti to investigate the parasites of the coconut scale with a view to their introduction into Fiji. Circ. Info. Fiji Dept Agr. **1**(7) : 137.

Recorded as doing considerable damage in the Cook Islands.

1921. Histerid Beetle, *Plaesius javanus*. Agr. Circ. Dept. Agr. Fiji **2**(3) : 44.

Recovery of *P. javanus* eight years after being introduced.

1922. Coconuts and bananas on certain islands around the coast of Vitilevu. Agr. Circ. Dept. Agr. Fiji **2**(5): 102–104 (1921).

Generally present but not very injurious; worse where dry than where wet.

1922. Introduction and notes. Agr. Circ. Dept. Agr. Fiji **2**(5) : 111 (1921).

Very injurious at Nasinau; trapping stated to be fairly effective.

1922. Visit to Fotuna and Wallis Island. Agr. Circ. Dept. Agr. Fiji **3**(2) : 20.

Reported as not present.

1922. Entomological Division. Dept. Agr. Fiji Ann. Rept. for the year 1921. Council Paper 56, p. 7.

Poor condition of banana industry largely due to attacks of weevil; trapping caught large numbers of the weevils; believes *P. javanus* now established.

1923. Report by the government entomologist. Dept. Agr. Fiji Ann. Rept. for the year 1922. Council Paper No. 46, p. 4.

Additional specimens of *P. javanus* recovered in the field.

* 1924. Report on Mission to New Guinea, Bismarks, Solomons and New Hebrides. Legislative Council Fiji, Council Paper, Suva, February.

Reported as abundant in New Hebrides. (Rev. Appl. Ent. 12: 300, 1924.)

1929. Some experiments to ascertain the part played by flight in the dispersal of the banana borer, *Cosmopolites sordidus* in Fiji. Agr. Jour. Dept. Agr. Fiji, **1**(3): 22–26 (1928).

Flight very occasional and a negligible factor in dispersal.

* **Small, W.** 1921. Annual report of the acting entomologist for 1919–20. Uganda Dept. Agr. Ann. Rept. 1919–20, p. 41.

Statement that inquiries had been received with reference to *C. sordidus*. (Rev. Appl. Ent. 9: 319, 1921.)

Smith, F. E. V. 1929. Report of the acting government entomologist. Ann. Rept. Jamaica Dept. Agr. for year ended 31st. Dec. 1929, p. 20.

Continues troublesome, especially in "ratoon" fields; paradichlorobenzene not so satisfactory as previousy expected.

Smith, R. C. and **Audant, A.** 1930. The more important injurious insects of Haiti. Jour. Econ. Ent. **23**(6): 976.

"Widely distributed and serious."

* **Sturm, J.** 1826. Catalog meiner Insecten-Sammlung. (Verzeichniss der. . . vörrathigen Insecten) Thl. 1. Nürnberg. Käfer. pp. VIII, 207 (16). 4 pls. Col., 8°.

Swezey, O. H. 1924. Notes on insect pests in Samoa. Hawaiian Planters' Rec. **28**(2): 217–218.

Brief; the insect probably only recently established and not as yet generally distributed; injury briefly described; serious in Fiji and control difficult.

Torres, I. L. 1927. El gorgojo del ñame del guineo (*Cosmopolites sordidus*). Rev. Agr. Puerto Rico **9**(2)56–58, 2 figs., August.

General popular account for Porto Rico.

Tryon, H. 1917. Report of the entomologist and vegetable pathologist. Queensl. Ann. Rept. Dept. Agr. & Stock for 1916–1917, p. 51.

Brief statement of distribution in Queensland; has occasioned proclamation of a special Regulation for its suppression but still very prevalent locally.

1920. The banana weevil (*Cosmopolites sordida* Chevr.). Considerations influencing methods of repression. Queensl. Agr. Jour. **13**(5) : 222–223.

Good description of methods of use of (*a*) traps, (*b*) removal of infested suckers, (*c*) destruction of beetles by starvation, (*d*) reducing egg-laying.

Tryon, H. and **Benson, A. H.** 1920. The banana weevil (*Cosmopolites sordida* Chevr.) Queensl. Agr. Jour. **13** (4) : 165–168, 5 figs.

Brief general account.

* **Urich, F. W.** 1916. Insect pests in Trinidad. Entomologist's Rept. Minutes Meet. Bd. Agr. Trinidad, pp. 1–56.

Reported from some localities in Trinidad; recommends destruction of infested stools, ploughing, forking and liming land; the Histerid beetle will be tried. (Rev. Appl. Ent. 5: 171, 1917).

* 1925. The plantain weevil. Bul. Dept. Agr. Trinidad and Tobago, **21**(1) : 40–42, 1 pl.

General account for Trinidad; the usual control measures recommended, including submerging suckers in water for 48 hours (Rev. Appl. Ent. 14: 176, 1926).

Veitch, Robert. 1926. Report of the chief entomologist. Ann. Rept. Dept. Agr. and Stock Queensland for 1925–1926 : 135.

Mention of publication of complete account as Bul. 4 and four introductions of *Plaesius javanus* noted.

1927. Report of the chief entomologist. Ann. Rept. Dept. Agr. and Stock Queensland for 1926–1927 : 69.

Brief mention of history of investigations; trapping with Paris green baits best; *Plaesius javanus* introductions apparently established.

1928. Report of the chief entomologist for year ending June 30, 1928. Dept. Agr. and Stock Queensland (as a separate publication of 8 pp.), p. 1.

Mention of Frogatt's trip to Java to import the predators—*Chrysopila ferruginosa* Weid. and *Plaesius javanus* Er.

Veitch, R. and **Simmonds, J. H.** 1929. Pests and diseases of Queensland fruits and vegetables. Queensland Dept. Agr. and Stock, pp. 106–112, pls. 26 and 27.

Full account.

Walters, E. A. 1926. Control of insect pests. Rept. Agr. Dept. St. Lucia, 1924, p. 9.

Widely distributed throughout the Colony and attacks all kinds of bananas; digging out and chopping up infested stools and soaking in lime water for 48 hours were both used.

1926. Viability of the weevil (*Cosmopolites sordidus* Germar) and the banana borer (*Tomarus bituberculatus* Beaud.) Rept. Agr. Dept. St. Lucia for 1925, p. 8.

Immersing weevils for 48 hours in water not effective; soaking infested plants in lime water for 48 hours recommended and has been adopted.

Ward, F. S. 1930. Banana growing in Malaya and the presence of diseases. Malayan Agr. Jour. **18**(2) : 70.

Greatest damage on poor soils; refers to suggestion of Dr. Wardlaw who thinks this insect may be an important accessory factor as a wounding agency in connection with Panama disease and refers also to experiments of Dr. Wardlaw of Imp. Col. Trop. Agr. (Trinidad) that innoculation experiments show that the borer enters the rhizome after the disease is established.

Watts, Sir Francis. 1917. Banana borer. Jour. Jamaica Agr. Soc. **21** : 169–173.

Description by the Commissioner of Agriculture of W. Indes of distribution in St. Andrews section, injury, etc., of weevil; contends attacks primarily weakened plants; need thoro survey and research.

Whitney, L. A. 1927. Report of the division of plant inspection, January 1925—December 1926. Rept. Bd. Agr. & Forestry Hawaii 1925–1926, pp. 48–57.

Brief note recording interception on abaca plants (*Musa textilis*) from the Philippines.

Wolcott, G. N. 1922. Informe anual de la división de entomología para el año fiscal de 1921 a 1922. Informe An. Est. Exp. Ins. Río Piedras, Puerto Rico, 1921–1922, pp. 59–60. (Also in English ed., pp. 48–49, 1923.)

Brief account of discovery in Porto Rico (Dec. 1, 1921); life history, injury and control.

1922. Vaquitas de importancia económica en Puerto Rico. Porto Rico Ins. Exp. Sta. Circ. 60, pp. 11–12, 2 figs.

Brief description of injury; recommends attracting and destroying weevils by means of freshly sliced rhizomes.

1924. Entomología económica puertorriqueña. Est. Exp. Ins. Puerto Rico Bol. 32: 58–59.

Brief general account.

1924. Insectae portoricensis. Jour. Dept. Agr. Porto Rico **7**(1): 135 (1923).

Listed from several localities in Porto Rico.

1924. Annual report of the division of entomology for the fiscal year 1922–23. Ann. Rept. Ins. Exp. Sta. Porto Rico, fiscal year 1922–3, p. 55.

Experiments interrupted but preliminary results indicate that daily collections from traps must be continued for several months before improvement of plants is shown.

1926. Insect pests in Haiti. Internat. Rev. Sci. & Pract. Agr. N. S. **4**(1): 188.

"Bananas are attacked by the root borer, *Cosmopolites sordidus* Germar.

1927. Entomologie d' Haiti. Published under the direction of the Service Technique, Dept. Agr. Haiti, pp. 253–256, 391–392, 2 figs.

Brief general account; generally distributed thruout Haiti.

THE EFFECT OF MOSAIC ON CELL STRUCTURE AND CHLOROPLASTS

MELVILLE T. COOK

This is a continuation of previous studies, the results of which were presented at the meeting of American Phytopathological Society, December 1926 and at the DesMoines Meeting of the same society in December 1929 and which have been published in the Journal of the Department of Agriculture of Puerto Rico (Vol. X Nos. 3 & 4, 1926 and Vol. XIV, No. 2, 1930).

In the previous studies the writer called attention to two points in the reaction of the hosts to the disease. (1) The disease inhibits the development of the meristematic tissue so that there is very little or no differentiation after the virus comes in contact with it. (2) The inhibition of the chloroplasts for a time. These points have been discussed to a greater or less extent by other writers previous to my own studies. Woods (1902), Iwanowski (1903), Melchers (1913), Doolittle (1920), Matsumota (1922), Rand (1922), Dickson (1922), Rawlins and Johnson (1925) and Goldstein (1926).

During the past year opportunity was offered to continue this work on other plants and it was thought desirable to do so, in order to determine if the laws held true in all cases.

The first plant for consideration at this time is the pepper which confirms in every detail the results of the writers studies on the tobacco and tomato, except that the process is much more rapid which is in harmony with the growth of the plant. The pepper leaves open and attain full size more rapidly than either the tobacco or tomato and the leaves on the new shoots are much closer together.

These studies were made on several plants. Seven leaves were taken from the one selected for the drawings. The first three did not show the mosaic pattern. The next showed a distinct pattern and in the sixth and seventh chlorotic areas were becoming green and the pattern indistinct. A corresponding series of leaves were taken from a healthy plant.

The section of the first leaf showed an undifferentiated tissue, with very few small chloroplasts (Fig. 1). The second showed the formation of a palisade layer and a larger number of chloroplasts (Fig. 2) while the third showed that some of the palisade cells had

divided which is an indication of a mild form of the disease (Fig. 3). The fourth showed practically the same conditions except that the chloroplasts continued to increase in size and number (Fig. 4) and the mesophyll was slightly better developed. A series of four drawings made from the leaves of the normal plant (Figs. 5 to 8) showed that the youngest leaf was more advanced in cell and chloroplast development than the second leaf from the diseased plants. The second leaf of the normal plant (Fig. 6) was better developed than the fourth leaf of the mosaic plant (Fig. 3). The third leaf of the healthy plant (Fig. 7) was nearly equal to the fifth leaf of the diseased plant. The fourth leaf of the normal plant (Fig. 8) was better developed than the fifth leaf of the diseased plant. In general, it may be said that the results correspond to the results of my previous studies, although not so pronounced.

An outbreak of the mosaic disease on *Crotalaria striata* gave the writer an opportunity to study the effects of the disease on this plant. A series of six leaves were taken from both diseased and normal plants. The results are as follows:

The first and second leaves on all plants studied were unopened and of course did not show the symptoms of the disease. In the section of the first or very youngest leaf of a diseased plant it was possible to distinguish the areas that were to become chlorotic from those that were to become green (Figs. 9 & 10). In the section from the chlorotic areas, the cells were undifferentiated and the chloroplasts few and small (Figs. 9 & 10) while in the sections from the areas that would have become green the palisade was slightly developed and the chloroplasts much more numerous and larger. These two drawings (Figs. 9 & 10) were made from a single section of a leaf. The third leaf of the diseased plants was not open and there was no visible pattern. Two sections from its leaf of the mosaic plant showed an increase in thickness, slight advance in cell structure which was greater in the section from the green area (Fig. 12) than in the section from the chlorotic area (Fig. 11) and a much greater development of chloroplasts in the green than in the chlorotic area. The development of both cell structure and chloroplasts was more advanced in the corresponding leaf from the normal plant than from the green area of the diseased plant.

The seventh leaf of the mosaic plant was open and the pattern distinct. The section (Fig. 13) from the chlorotic area was thin, the palisade very poorly developed, the mesophyll open, the chloroplasts few and about normal in size when compared with the chloro-

plasts of the normal leaf. (Fig. 14). The section (Fig. 15) from the green area of the diseased leaf was thicker but the cell structure showed the effects of the disease in the porly developed palisade. The chloroplasts were more numerous than in the chlorotic section (Fig. 13) but fewer than in the section from the normal leaf (Fig. 14). The ninth leaf of the diseased plant (Fig. 16) was thin, the palisade almost undeveloped but the chloroplasts were larger and more normal. The section from the green area was almost normal in every particular.

The papaya (*Carica papaya* L.) is a plant of the tropics and near tropics. A few years ago I noticed a disease of this plant on the station grounds, but the gardener destroyed it before I had time to study it. This or a similar disease was reported later by Dr. Ciferri of Santo Domingo under the name of curly leaf. Both Dr. Ciferri and myself are in doubt as to the exact cause of this disease but I am inclined to believe that it is due to a virus. A comparison of a section of a very young diseased leaf (Fig. 17) with a section of a very young normal leaf (Fig. 18) shows that the diseased leaf is thinner than the normal leaf and that the palisade is not so well developed. Passing to the fifth leaf of the diseased plant (Fig. 19) and the fifth leaf of the normal plant (Fig. 20) we find that the diseased leaf is about one-half as thick as normal leaf and not so well developed. The chloroplasts of the diseased leaf at this stage are almost equal to the chloroplasts of the normal leaf.

Two monocotyledonous plants were studied. The Amazon lily (*Eucharist amazonica*) and a hybrid Amarillis. The results of the studies on these plants were so nearly the same that drawings were made from the first one. It was impossible at the time this material was collected to find any plants that were not diseased. Therefore the sections are made from the chlorotic and the green areas of diseased leaves. These plants produce two or three leaves in rapid succession and then rest for a few months before producing another cluster. Two clusters are usually to be found on a plant. The material from which these studies were made was collected immediately following the unfolding of the youngest leaf of a new cluster and was from the three young and two old leaves.

The section from the chlorotic area of the youngest leaf was thinner than the section from the green area and without chloroplasts. The section from the green area of the same leaf showed many small chloroplasts (Figs. 21 & 22). The sections from next leaf were

thicker than those from the first leaf but the one from the chlorotic areas was thinner than the one from the green area. Both sections showed chloroplasts but they were more numerous in the thick than in the thin area (Figs. 23 & 24). In the third leaf both areas were thin but the section from the green area showed a higher development in that there were numerous intercellular spaces. Also the chloroplasts in the green area were larger and more numerous than in the chlorotic area (Figs. 25 & 26).

The two older leaves were less succulent than the three young leaves and the sections showed that they were thinner. In both old leaves the sections showed more chloroplasts in the green than in the chlorotic areas but for some unexplained reason those of the green areas were slightly smaller than those from the third leaf of the new cluster.

EXPLANATION ON PLATES

Fig. 1.—Section from youngest leaf of mosaic pepper.

Fig. 2.—Section from second leaf of same plant.

Fig. 3.—Section from the third leaf of the same plant. Note the divisions in three of the palisade cells which indicates a mild form of the disease and the increase in number and size of chloroplasts which is probably the result of age and exposure to sunlight.

Fig. 4.—Section from the fourth leaf. Note that palisade is not so well developed as in the normal leaf (Fig. 8). Also note the increase in the size of the chloroplasts as compared with Fig. 3.

Figs. 5 to 8.—Sections from the four youngest leaves of a healthy plant for comparison with the corresponding leaves of the diseased plant (Figs. 1 to 4).

Figs. 9 & 10.—Sections from the chlorotic areas of a young leaf of a mosaic plant of *Crotalaria striata*. Note that Fig. 10 is better developed than Fig. 9.

Fig. 11.—Section from the chlorotic area of the next older leaf of the same plant.

Fig. 12.—Section from the green area of the same leaf. Note the greater development in both cells and chloroplasts.

Fig. 13.—Section from the chlorotic area of the seventh leaf of the same plant.

Fig. 14.—Section from the seventh leaf of a healthy plant.

Fig. 15.—Section from the green area of the same leaf as Fig. 13

Fig. 16.—Section from the chlorotic area of the ninth leaf of the diseased plant.

Fig. 17.—Section from a very young diseased leaf of *Papaya carica.*

Fig. 18.—Section from corresponding leaf of a healthy plant.

Fig. 19.—Section from an older leaf of a diseased plant.

Fig. 20.—Section from a corresponding leaf of a healthy plant.

Figs. 21, 23 & 25.—Sections from the chlorotic areas of a diseased plant of *Eucharist amazonica.*

Figs. 22., 24 and 26.—Sections from the green areas of the same leaves.

PLATE IX.

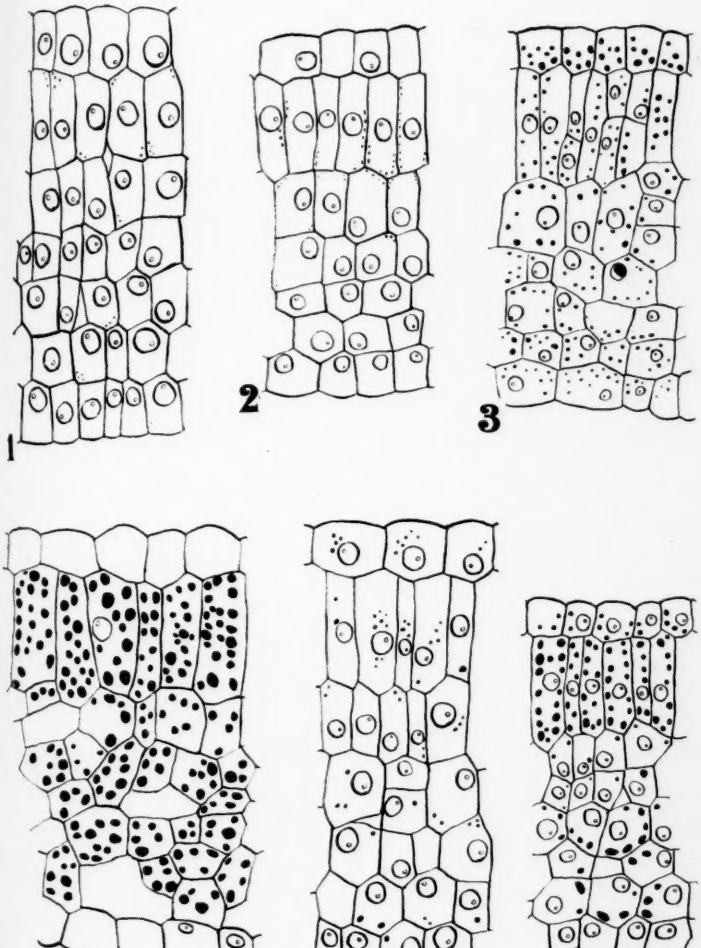
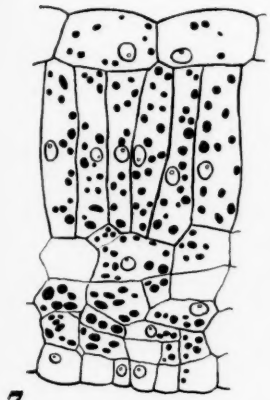
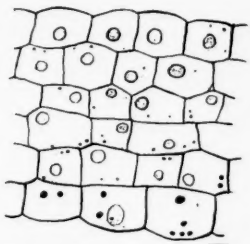


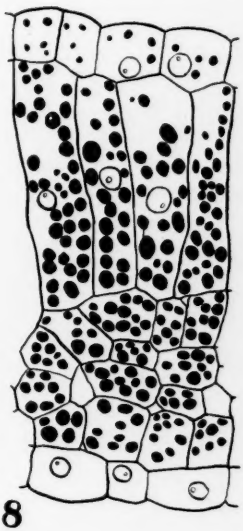
PLATE X.



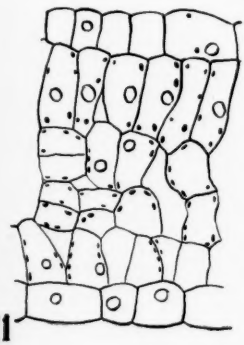
7



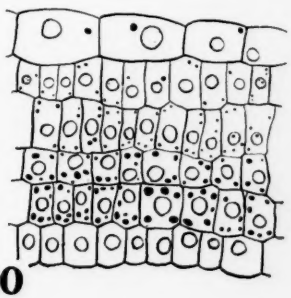
9



8

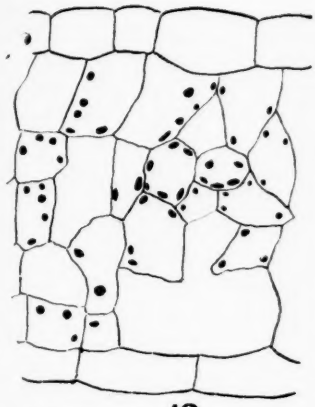


11

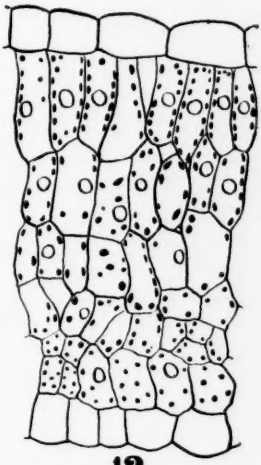


10

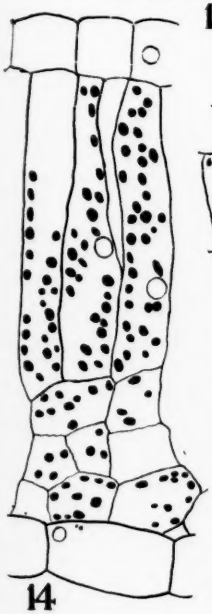
PLATE XI.



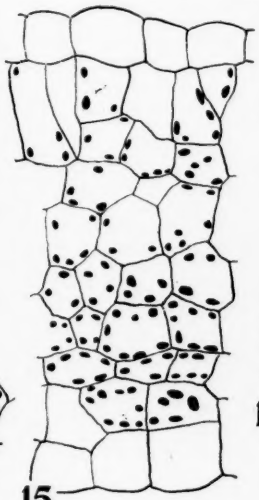
13



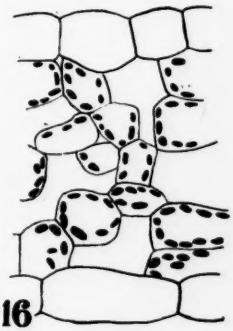
12



14

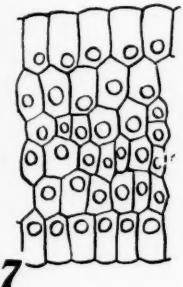


15

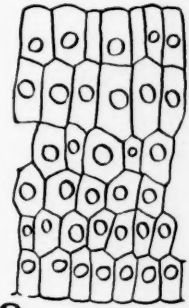


16

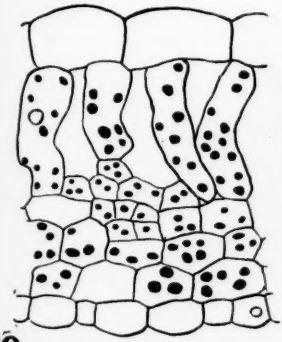
PLATE XII.



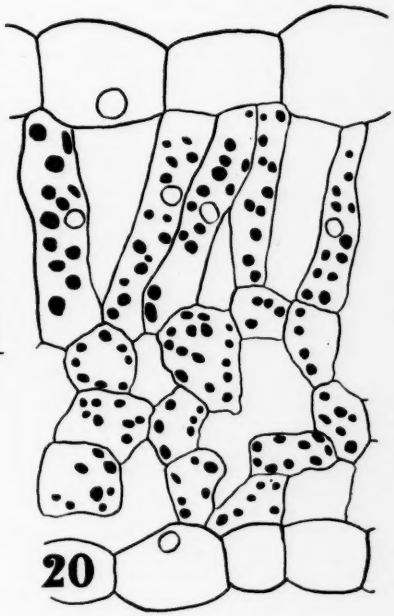
17



18

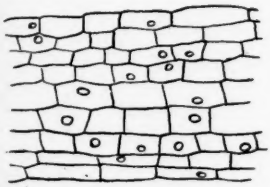


19

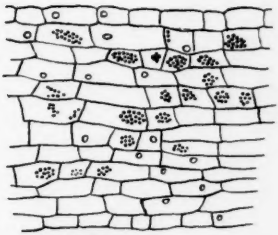


20

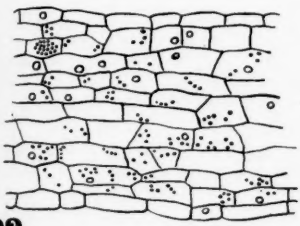
PLATE XIII.



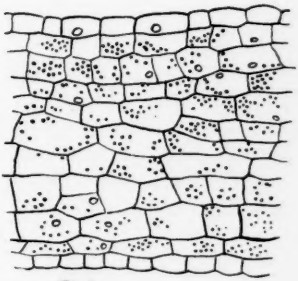
21



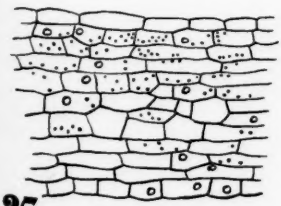
22



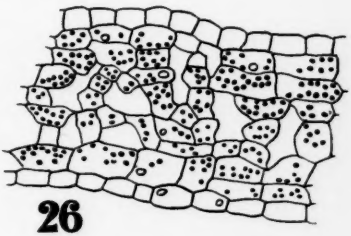
23



24



25



26

THE LEAF SPOT OF TOBACCO; AN AFTER SYMPTOM OF MOSAIC

MELVILLE T. COOK

Soon after coming to Puerto Rico in 1923 the attention of the writer was called to a peculiar spotting on the leaves of tobacco. Collections of these spotted leaves were sent in from time to time and were examined for fungi and bacteria but the results were always negative. The disease appeared to be of minor importance and no special studies were made until the winter of 1929–30. These spots were always on the mature, usually the lower, leaves of the plants. They were 2 to 5 mm. in diameter, white, brown or black and composed of dry, dead tissues. During the winter of 1929–30 great numbers of these spots were found one morning in tobacco mosaic experimental plots. These plots were not more than 50 feet from my laboratory and it was my habit to visit them nearly every day. Therefore, it was evident that these spots developed in a very short time. A careful examination showed that these spots were on the mosaic plants and not on the healthy plants and that they were always on the old leaves which did not show the symptoms of the mosaic, *i. e.* on leaves, which due to late inoculations, had not developed the symptoms or on leaves from which the pattern had disappeared. The following morning the spots were much more numerous. Plants which did not show these spots were marked and observed from day to day and it was soon learned that plants which did not show those spots one day might show a considerable number the following morning. A block of plants was then divided into two parts and the plants in one part inoculated. In due time the spots appeared on old leaves of the diseased plants.

These spots remind one of the early studies by Mayer, Iwanowski and others. Mayer (**10**) reported a spotting in the late stages of the tobacco mosaic. Iwanowski stated that Mayer had confused two diseases and that the spots were a disease which had been described by himself and Polowzoff under the name of "pockenkrankheit".

He says:

"This last name I retain for that disease which is the subject of this paper, and as I have just described it *never manifests itself in the form of dry spots.*"

In 1894 Prillieux and Delacroix described spotting of the leaves

of the tobacco under the name of "nielle" and from which they claimed to have isolated a motile bacillus. Some workers have supposed that this disease was the same as Mayer's "mosaikkrankheit" but this is extremely doubtful.

In 1897 Marchal described a disease under the name of "La Mosaique du Tabac" which was probably the same as the disease described by Mayer. He emphasized the presence of the spots which he also described as containing a motile bacillus.

In 1898 Beijerinck published a paper on tobacco mosaic in which, judging from the description, there is no doubt that he was studying the mosaikkrankheit of Mayer. One of his illustrations shows a spotting which is the same or similar to the spotting described by Mayer and others.

In 1898 Sturgis of Connecticut published a preliminary note on two diseases of tobacco in which he said:

"If allowed to remain, the paler portions of the mottled leaf loss their green color and the whole leaf becomes yellow and sprinkled over, especially towards the tip, with small circular spots where the tissues are bleached dead and brittle."

Later on in the same paper he says:

"If that can be called a disease which is characterized by symptoms such as tobacco-growers desire to see in moderation, which enhance the market value of the leaf and which can be induced artificially with profit, then the 'spotting' of tobacco comes under this head. It is a peculiar disease, never very common, nor confined to any one locality and not characteristic of any special soil. What its earliest stages are I am unable to say, inasmuch as it is imposible to predict when it will occur and therefore to be on the watch for its first appearance, and, furthermore, because it only becomes noticeable when well advanced. As I have seen it in the field and in specimens sent to the Station, it is signalized by the presence on the leaf of small circular spots. These usually occur in the greatest number at or near the tips of the leaves and, at first, are yellowish in color and somewhat irregular in outline. Later they take on a circular form and become marked off from the surrounding tissue by a narrow border of a darker color. The tissue within this border finally dies and becomes almost white, but, except in severe cases, it does not break away from the leaf. A leaf so affected looks as though it had been sprinkled over with some caustic substance which has killed the tissues without disintegrating them. It bears a close resemblance also to the 'leaf-spot' caused on certain plants by the attacks of fungi. Sometimes the spotting is slight and the spots themselves are scattered evenly over the whole leaf-surface; in such cases buyers are willing to pay a higher price for tobacco, spotted wrappers being in demand. The spot can be successfully imitated by spraying the ripening leaves with a caustic liquid, and, where this is well done, the tobacco also brings a higher price.

"It is only when the spot invades practically the whole leaf and causes the breaking of the tissues that it does serious damage. I have already repeatedly, but thus far unsuccessfully, attempted to discover the primary cause of this

trouble both by consulting the opinion of experienced tobacco-growers and by careful microscopic examination of the spots. Some say that it is to particles of sand adhering to the leaves; others that it is caused by drops of water, which, acting as lenses, burn the leaf where they rest; but with regard to these theories it is sufficient to say that they have been put to proof in many attempts to produce the spot artificially and have signally failed. Scores of the spots have been microscopically examined during the past three years without showing any evidence of the presence of fungi, insects or bacteria. Nothing further, therefore, can be said regarding this trouble, nor would it have been considered worthy of mention at present were it not for its resemblance to a disease of tabacco which occurs in Europe and Asia."

In 1902 Woods referred to a spotting of mosaic tobacco leaves which he described as follows:

"In field conditions as a final stage the swollen green area became marked with small dead spots, but these did not appear in plants grown under glass."

In 1914 Clinton reported a spotting of mosaic tobacco leaves which he described as:

"A serious leaf injury known locally as 'rust' often occurs on the older calicoed leaves. It shows as small, roundish, reddish-brown spots of dead tissue, more or less thickly covering the leaves; sometimes these merge into large irregular areas, resembling sun scorch injury of the plants. This is probably the same trouble described by various European writers as 'pockenkrankheit', ascribed by some to bacteria. In this state rust is not a necessary accompaniment of calico, but rarely if ever occurs except on leaves showing calico or signs of suppressed calico. We believe that it is of the nature of sun scorch, since it usually occurs in bright, hot weather, suddenly following a rainy or cloudy period, and that it develops on calicoed leaves because of their weakened conditions."

Material from these spots and the surrounding tissues was prepared for embedding and sectioning. The writer was especially interested in this work because of his previous studies which led to the conclusion that the chlorotic areas were the result of inhibition and disintegration of the chloroplasts.

A careful study of both free hand and microtone sections of these spots showed that the spots originated in the palisade cells (Figs. 1 to 8). It was impossible to determine whether they originated as small spots which gradually enlarged or whether the spot was full sized from the beginning but the fact that the spots develop during a single night indicates that they are full sized from a very early stage in their formation. The sections revealed many spots which consisted of a single cell and which could not be detected with the unaided eye (Fig. 2). Others ranged from small groups of a few cells (Figs. 1 to 9) to areas 5 mm. or occasionally more in diameter. The dying of the palisade cells is followed

by a dying of the cells below. This usually continues until all the cells from the upper to the lower surface are dead (Figs. 5 to 10). It appears that the palisade and upper epidermal cells may be the only dead cells of the spots on the morning of the first day and that the lower cells die later. Occasionally dead mesophyll cells are found in positions unrelated to the spots.

Efforts were made to study the disintegration of the cell contents but very little was learned about it probably due to the fact that it appears to break down during the night. However, the entire cell content appears to disintegrate into a homogenous black mass which dries and shrinks from the cell wall. The next step in this process is the collapse of the upper epidermis (Figs. 6, 7, 8, 9). The next step is the breaking of the cell walls throughout the entire area (Figs. 7, 8, 9). The final step is the contraction and drying so that the entire area becomes thin, dry and brittle (Figs. 9 & 10).

A careful study of other tobacco plants has shown similar spots on leaves of plants with other diseases and on leaves that were past maturity, but these were not so common or so abundant as on the mosaic plants. A few spots were also on leaves of pepper plants which had been inoculated with the tobacco virus.

Note: Since the preparation of this manuscript for publication, Johnson and Hoggan have published a paper (**8**) in which they say:

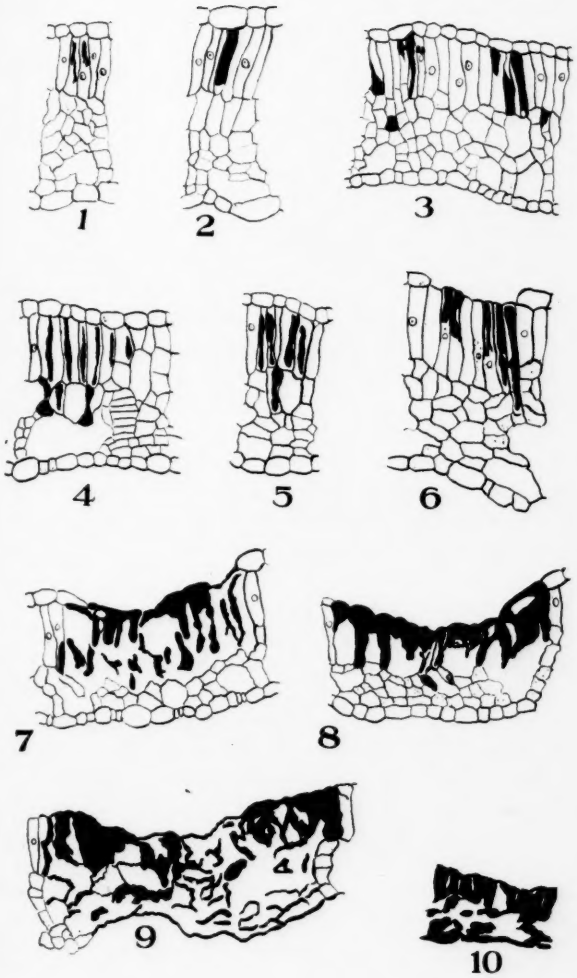
"Soon after Mayer's work became known, it was claimed by some that his 'Mosaikkrankheit' of tobacco included two distinct diseases, one the true infectious mosaic and the other a supposedly unrelated disease known elsewhere as 'Pockenkranheit'. Although much attention was given to the subject, this disagreement has presisted almost to the present time, though it is now quite generally conceded that Mayer was correct in his interpretation that necrosis is one of the symptoms of the ordinary tobacco mosaic virus on tobacco as well as on certain other hosts."

LITERATURE

1. **Beijerinck, M. W.** Over een contagioum vivum Fluidum als Oorzaak de Veeckziekte der Tobaklladen. Verslag Koninkl. Akad. van Wetensch. te Amsterdam, Wis. en Natuurk. Afd. van Zaterdag. 6: 229–235. 1898.
2. ————————On a Possible Cause of the Leaf Spot on Mosaic of Tobacco. Centbl. Bkt. u. Pav. 2 Abt. 5(1): 27–32. 1899.
3. **Clinton, G. P.** Chlorosis of Plants with Special Reference to Calico of Tobacco. Conn. Agri. Exp. Station Report for 1914: pp. 357–424. (1915).

4. **Cook, Mel. T.** Histology and Cytology of Sugar Cane Mosaic Journ. of the Dept. of Agric. of Puerto Rico. 9: 5–27. 1925.
5. ———————The Effect of Mosaic on the Content of the Plant Cell. Jour. of the Dept. of Agric. of Puerto Rico. 10: 229–238. 1926.
6. ———————The Effect of Some Mosaic Disease on Cell Structure and on the Chloroplasts. Journ. of the Dept. of Agri. of Puerto Rico. 14: 69–101. 1930.
7. **Iwanowski, D.** and **Polowzoff, W.** Ryabucha bolesn Tobaka, eja pritschini i srelstwo borbi s nejn (The Leaf Spot of the Tobacco). Mem. Acad. Imp. Sci. St. Petersburg 7, (37). 1890.
8. **Johnson, J.** and **Hoggan, I. A.** The Challenge of Plant Virus Differentiation and Classification. Science 73: 29–32. 1931.
9. **Marchal, Em.** La Mosaique du Tobac (Tobacco Mosaic) Revue Mycologique 19: 13, 14. 1897.
10. **Mayer, A.** Ueber die Mosaikkrankheit des Tabaks. Landw. Versuchs stat 32: 450–467 (1886) Abstract in Journ. of Mycol. 7: 382–385. 1894.
11. **Prillieux** et **Delacroix.** Maladies Bacillaires de Divers Vegetaux (Bacterial Diseases of Some Plants) Compter Rendus 118: 668–671. 1894.
12. **Sturgis, W. C.** Preliminary Notes on Two Diseases of Tobacco. Comm. Agri. Expt. Station Report for 1898 pp. 242–260.
13. **Woods, A. F.** Observations on the Mosaic Diseases of Tobacco. U. S. Dept. of Agric., Bureau of Plant Industry Bull. 18. 1902.

PLATE XIV.



SOME UNDESCRIBED SYMPTOMS OF MOSAIC IN PORTO RICAN TOBACCO

MELVILLE T. COOK

In discussing the symptoms of mosaic in plants, it is necessary to take into consideration many factors, such as:—the host, the strain of virus and the environment. It is well known that the symptoms resulting from the use of a definite virus on different species within a genus or sometimes on varieties within a species may be different or that the host may be a symptomless carrier of the virus. It is also well known that the symptoms vary with the strain of the virus and with environmental conditions. It should also be remembered that the response of the host to the disease may vary with the age of the host and with the rate of growth and that the rate of growth depends in a great measure on the environment.

It is very generally recognized, although not emphasized in the literature that the symptoms may undergo changes with age. The symptoms of mosaic in many plants are usually well defined on the younger leaves but the chlorotic areas gradually become green with age, so that it is impossible to distinguish the patterns on the older leaves.

Unfortunately some of the workers, following the lead of Beijerinck, Koning and other early investigations have persisted in assuming that the chlorotic areas in mosaic plants were the results of a disintegration of the chloroplasts although if this were the case the chlorotic areas should become more chlorotic with age instead of becoming green as is the case in the common mosaic of tobacco, sugar-cane and many other plants. It has also been assumed that the chlorotic areas increase in size as a result of the invasion of the green areas by the virus from the chlorotic areas. Both of these ideas have been contradicted by the writer in previous papers. In many of the mosaic diseases, the chlorotic areas gradually become green with age, the leaf may become uniformly green and the mosaic pattern disappears. The writer has expressed the opinion as a result of the study of several mosaic diseases that the chlorotic areas are not due to desintegration of the chloroplasts but to an inhibition of their development. Later in the growth of the leaves this inhibition is overcome and the chloroplasts increase in size and number. The writer has also expressed the opinion that

the chlorotic areas do not increase in size as a result of the invasion of the surrounding cells by the virus but that the increase in size is a result of cell growth and division. However, my statements have not applied to the lesions which are characteristic of some of the virus diseases because I have had no opportunity to study them.

The tobacco mosaic of Porto Rico may be described as the common type in which we find irregular green and white areas. In some cases there is the blistering or pocketing which has been described in many publications but this symptom is not prominent. In very severe cases the entire plant may be a light yellow or almost white, the leaves small, rather brittle and the margins turned down. There are several modifications of the pattern but thus far the writer has been unable to separate these types and for the present must consider them as symptom variation due to the same virus. This virus will also produce mosaic on tomatoes and pepper and when transferred back to tobacco the symptoms are the same as on the original tobacco plant from which the virus was obtained. It can also be transferred between tomato and pepper and will give the characteristic symptoms on each. The symptoms on the tomato are a slight reduction in size of the leaves, a mottling and the reduction of some of the basal leaflets to short spurs consisting of little more than a midrib.

When tobacco plants are inoculated with a hypodermic needle, inserted at the node, the symptoms appear in from five to ten days, occasionally earlier on the very young leaves. These inoculations were made at various heights on the plants. The typical symptoms developed on the new foliage at the top of the plant and on new shoots at any point on the plant. However, it is the symptoms on the older leaves which were formed previous to inoculation to which the writer wishes to call your attention at this time.

If the mosaic is a disease of the meristematic tissue as stated by various writer in the past or to state the case from the more modern view point, if the meristem is the only tissue that responded to the influence of the virus, will symptoms be developed in the leaves in which the tissues were fully differentiated? These experiments indicated that the typical symptoms rarely developed on the old leaves, that is the leaves that had reached their full size did not show any symptoms; and that the symptoms on leaves that were not quite full sized at time of inoculation, but in which the tissues were fully differentiated sometimes developed more or less circular areas which are sightly lighter in color that the surrounding parts of the leaves. This was due to the inhibition of the chloroplasts.

The effect of direct inoculation into the mesophyll of the leaves was tested by the following method.

Leaves ranging from one to two inches in length were inoculated by rubbing with cheese cloth soaked in juice from a mosaic plant. In from five to ten days circular spots about ten to twelve millimeters in diameter appeared. These spots were slightly lighter in color than the other parts of the leaf. When these leaves were held to the light, similar areas could be detected in other parts.

The tobacco plants of fifteen leaves each were inoculated by rubbing the leaves on one side of the plant with cheese cloth soaked in juice from mosaic plants. The leaves were measured at time of inoculation and later to determine which, if any, had made their full growth. In five days three of the inoculated leaves on one plant and four on another plant developed areas as described. Five leaves on the third plant developed symptoms in six days. This experiment was repeated several times with similar results. Symptoms were very rarely developed on the uninoculated leaves. No spots appeared on leaves that were full sized before inoculation.

A study of the histology of the leaves of different ages showed (1) that when the tissues were not fully differentiated at time of inoculation, there was an inhibition of the development of both cell structure and chloroplasts and that the younger the leaves the greater the inhibition; (2) that when chlorotic areas were formed on leaves in which the tissues were fully developed, there was no change in cell structure but that the development of the chloroplasts had been inhibited; (3) that the enlargement of these areas which occurs on the young leaves is due to cell division and cell growth and not to an invasion of the surrounding cells by the virus. Chlorotic areas did not appear in leaves that had reached full size previous to the inoculation.

NEW VIRUS DISEASES OF PLANTS IN PORTO RICO

MELVILLE T. COOK

During the past year six previously unreported virus diseases have been studied by the writer but some of them had been observed previous to this time. Descriptions are published at this time for the purpose of record and the convenience of the workers.

The mosaic of *Crotalaria striata* DC, is becoming quite abundant in Porto Rico. The patterns are well defined mosaics of dark and light green in which either color may predominate. In some cases the leaves are almost entirely light green or yellow. Occasionally plants are dwarfed by the disease. Severely diseased plants produce few or no seeds. Tests with seeds from diseased plants have thus far given healthy plants. Field observations indicate that the disease is carried by insects. Well advanced plants that have not shown symptoms of the disease frequently develop the disease in the new growths. The writer has demonstrated that the disease can be transmitted by inoculation with juice from diseased plants.

The mosaic of *Commelina longicaulis* Jacq., was first found on the little island of Vieques. This plant grows as a weed in many of the West Indies. The symptoms are rather large chlorotic areas, sometimes forming rings. The infected plants are as vigorous as the healthy and the symptoms do not appear unless the plants are making a vigorous growth. The symptoms disappear during periods of dry weather.

What appears to be a virus disease of *Carica papaya* L. attacked the plants in the Station grounds a few years ago but the gardener destroyed the plants before the writer could make a study of them. This or a similar disease was later described by Dr. R. Ciferri of Santo Domingo as "curly leaf" but he was uncertain as to the cause. My histological studies indicate that it is a virus disease. The young leaves become more or less curled and in severe cases, this curling presists throughout the life of the plant. The lower leaves become yellow and fall. One or both symptoms may appear on the plants. Sometimes all the older leaves fall, leaving a cluster or rosette of leaves at the apex. In severe cases the fruits are reduced in number and size.

Abutilon hirtum (Lam.) Sweet, is a wild species of Malvaceae which shows a high percentage of diseased plants. The patterns

vary and the chlorotic areas are yellowish or white. The diseased plants are usually smaller than the healthy plants but many of them are full sized and do not appear to be injured by the disease. The diseased plants produce very few seeds. The writer has collected and sown a considerable member of these seeds but thus far the seedlings have not shown any symptoms of the disease. Field observation show that it spreads from plant to plant and indicate that it is carried by insects. This disease is interesting because of the fact that the variegated Abutilons which became so popular as ornamentals in Europe about seventy years ago are said to have come from the West Indies.

A mosaic disease is very common on *Sida carpinifolia* L. and *S. rhombifolia* L. and has the same characteristics as the one on *A. hirtum* and may be due to the same virus. This disease is abundant and the diseased and healthy plants may be found growing in contact.

Andenoropium gossypifolium (L.) Pohl. is subject to mosaic which is very common. The chlorotic areas are numerous, variable in size and form, frequently coalescing but very rarely covering the entire leaf. The chlorotic areas grow slower than the green parts which results in slight puckerings.

Ipomoea nil (L.) Roth, which grows abundantly throughout the island is subject to a mosaic which varies from a slight mottling with yellowish or almost white areas to leaves which do now show any of the green color.

Mr. Francisco Seín, Jr., Assistant Entomologist has called the attention of the writer to a mottling of the mulberry leaves. This disease appears as a mottling very characteristic of the mosaic. A second patter which appears as zigzag lines across the leaves may be due to the same cause. Mr. Seín tells me that he has transmitted this disease by means of scions.

EXPLANATION OF FIGURES

Figure 1.—Healthy and Mosaic leaves of *Crolataria striata*.

Figure 2.—Mosaic leaves of *Commelina longicaulis*.

Figures 3 & 4.—*Carica papaya* plant showing effect of a virus disease.

Figure 5.—Advanced stage of *Carica papaya* with a virus disease.

Figure 6.—A very small plant of *Carica papaya* dwarfed as a result of a virus disease. Note the normal plants on either side.

Figure 7.—Diseased leaf of *C. papaya*.

Figure 8.—Healthy leaf of *C. papaya*.

Plate No.——. One healthy and seven mosaic leaves of *Abutilon hirtum.*

Figure 9.—Mosaic leaves of *Sida carpinifolia.*

Figure 10.—Mosaic leaf of *Andenoropium gossypifolium.*

Figure 11.—Mosaic leaf of *Ipomoea nil.*

o-O-o

PLATE XV.

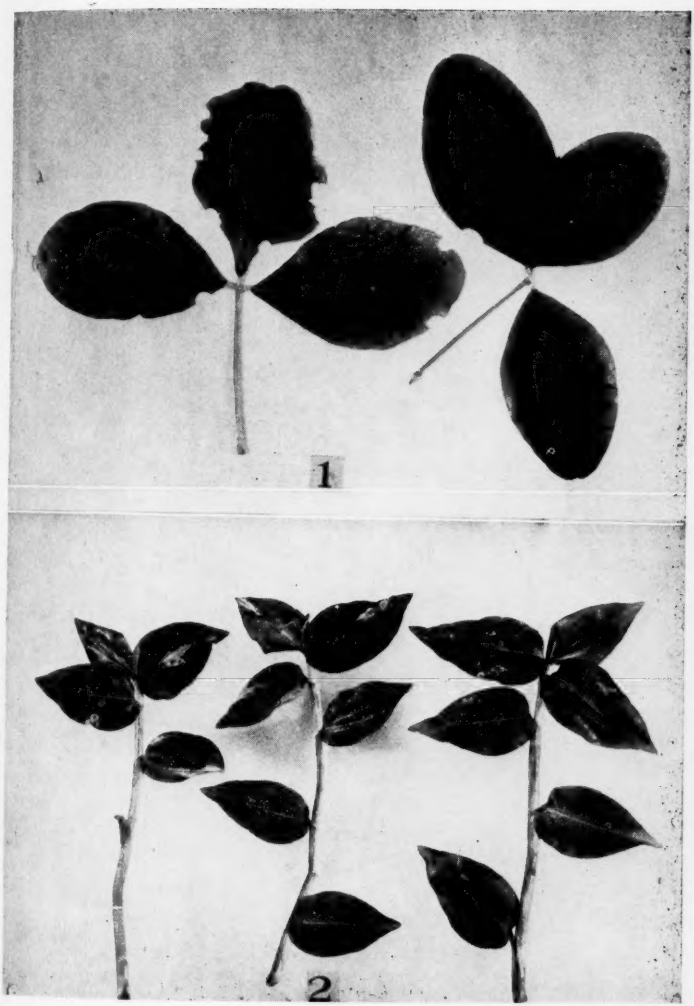
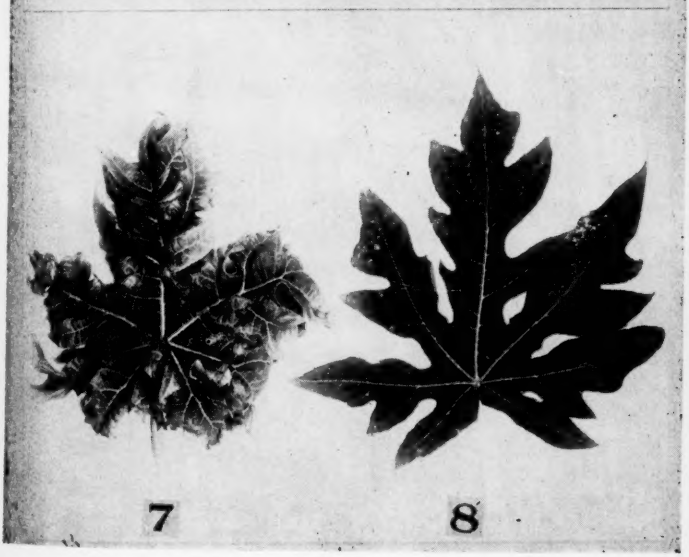


PLATE XVI.

PLATE XVII.

6



7 8

PLATE XVIII.

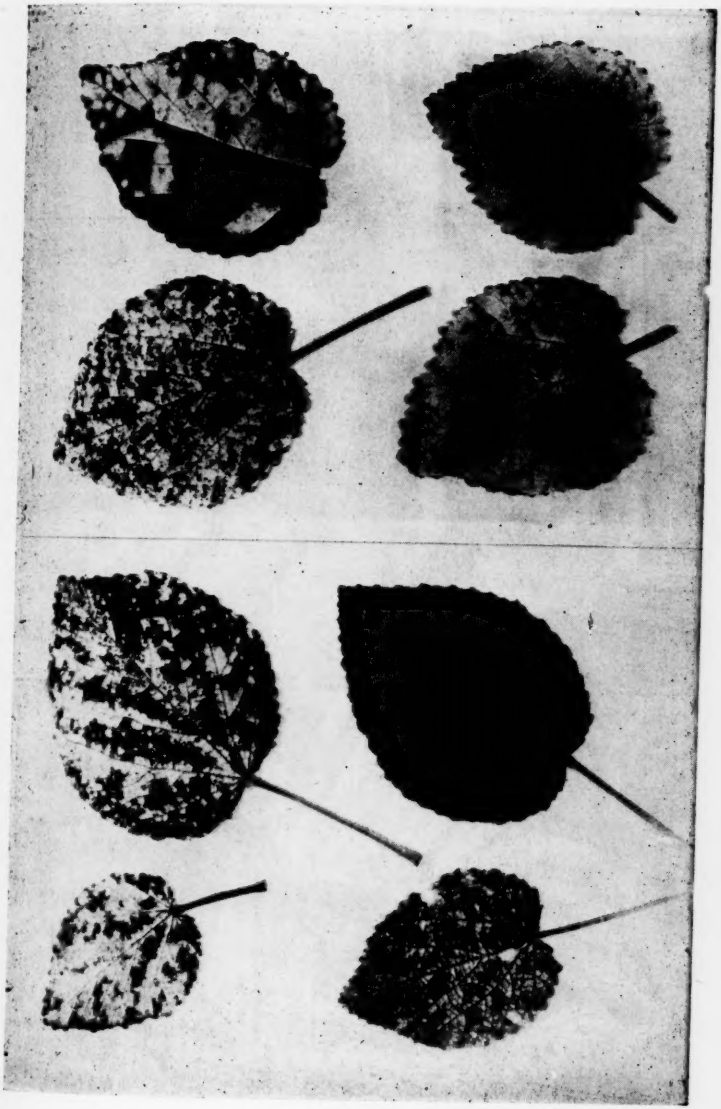
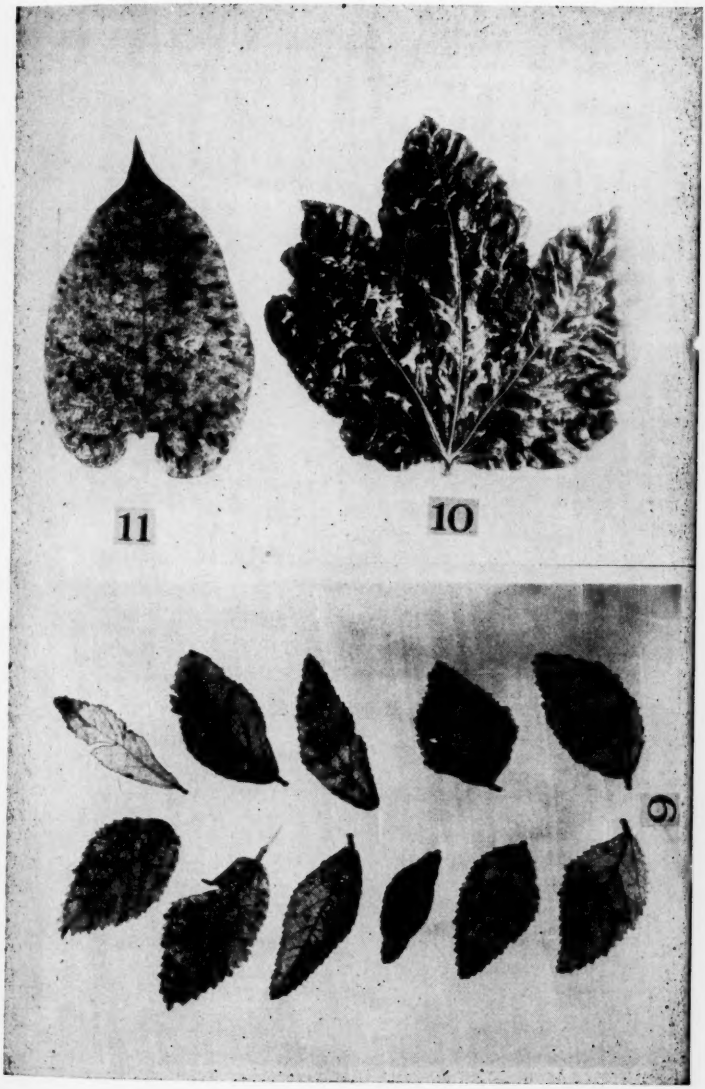


PLATE XIX.



THE JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF PORTO RICO

is published for the encouragement of the advancement of agricultural science in the American tropics in general, and especially in Porto Rico. Papers on Porto Rican science are given first preference for publication. In case of available space papers from other of the West Indies will be given second consideration and papers from other tropical American countries will be given third consideration. It is the policy of the JOURNAL to publish technical papers of fundamental value for the advancement of agricultural science in the American tropics. Although papers from other Tropical American countries will be received when space is available, those only will be accepted which may now or later prove of some direct or indirect value to Porto Rico.

EDITOR.